CALIFORNIA ENERGY COMMISSION

CALIFORNIA NATURAL RESOURCES AGENCY

California Energy Commission

CONSULTANT REPORT

2024 California Vehicle Survey

Full Report, Volume One

Prepared for: California Energy Commission

January 2026 | CEC-600-2026-003

California Energy Commission

Mark Fowler
Justin Curtis
Eric Kapner
Primary Authors

RSG
55 Railroad Row
White River Junction, VT 05001
(802) 295-4999
www.rsginc.com

Aniss Bahreinian
Commission Agreement Manager

Andre Freeman
Supervisor
TRANSPORTATION ENERGY FORECASTING UNIT

Quentin Gee
Branch Manager
ADVANCED ELECTRIFICATION ANALYSIS BRANCH

Aleecia Gutierez
Director
ENERGY ASSESSMENTS DIVISION

Drew Bohan
Executive Director

ABSTRACT

This report summarizes work performed for the 2024 California Vehicle Survey (CVS) project. The 2024 CVS includes revealed preference and stated preference surveys for the residential light-duty vehicle (LDV) and the commercial LDV market segments in California, as well as an additional survey section for respondents who own or lease zero-emission vehicles. The results of the survey are used to update the residential and commercial LDV choice models. These models will be used in generating the LDV energy demand forecast for the *2025 Integrated Energy Policy Report.*

The project yielded 3,890 complete surveys from residential respondents, including 1,031 zero-emission vehicle (ZEV) owners, and 2,029 complete surveys from commercial respondents, including 320 ZEV owners. Key results include roughly the same estimated utility for gasoline vehicles and BEVs among residential respondents and increasing estimated utility for autonomous BEVs among both residential and commercial respondents.

Keywords: California Energy Commission, 2024 California Vehicle Survey

Please use the following citation for this report:

Fowler, Mark, Justin Curtis, and Eric Kapner. (RSG). 2026. *2024 California Vehicle Survey.* California Energy Commission. Publication Number: CEC-600-2026-003.

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EXECUTIVE SUMMARY

Background

To support the development of the California Energy Commission's (CEC's) Integrated Energy Policy Report, CEC staff develop a transportation energy demand forecast. The forecast assesses transportation fuel demand and the outlook for retail fuel prices. As part of fuel demand analysis, the forecast considers shifts in fuels and vehicle types, as well as other factors based on analysis of data collected from different sources. The forecast is used by government agencies, utilities, fuel providers, and many others to plan infrastructure development, adjust energy policies, and implement emission reduction strategies. In essence, it enables better preparation for the evolving energy needs of California.

The CEC has access to data sources such as the Department of Motor Vehicles (DMV) registration database and the American Community Survey (ACS) for analysis of current household vehicle ownership and the household demographic composition, as well as commercial fleet owners in California. However, DMV data does not include income and other household demographic information, and the ACS data does not include data on fuel types of household vehicles. To supplement these data sources and update the light-duty vehicle demand forecasting models, the CEC periodically conducts the California Vehicle Survey (CVS), to gain insight into current and future transportation and energy technology choices and attitudes, and the factors that people consider when purchasing a new vehicle. The survey allows the CEC to collect economic and demographic data on each respondent, which enables analysis of factors that influence vehicle ownership and the types of vehicle choices consumers make. This data includes multiple categories, such as income, household size, employment, the number and fuel types of vehicles owned, and future ownership plans and attitudes.

As part of California's ongoing efforts to accelerate adoption of cleaner vehicles, the 2024 CVS includes key questions on zero-emission vehicle (ZEV) refueling, charging, use, purchase incentives, and satisfaction with technology and purchase experience. It also includes updated questions on consumer interest in autonomous vehicles (AV), solar panel and battery ownership, and potential vehicle-to-grid (V2G) behavior. This information is crucial for many purposes including updating the vehicle choice models used in development of the transportation forecast and helping to ensure that the forecast accurately reflects the rapidly evolving vehicle marketplace.

The survey team launched the survey project in Fall of 2023, and the data collection phase was completed in 2024. The final dataset is composed of 3,890 residential responses (including 1,031 residential zero-emission vehicle owners) and 2,120 commercial responses (including 685 commercial zero-emission vehicle owners). Detailed information on these survey responses is catalogued throughout this report.

Key Takeaways

The findings from this survey offer a clear look at factors shaping today's vehicle purchase decisions, from practical considerations like cost and fuel efficiency to evolving expectations around advanced technologies. The following takeaways summarize key insights and provide a foundation for understanding how consumer priorities are shifting in the automotive market.

ZEV ownership and experience make a difference in new technology adoption, which are reflected in some of the important takeaways from the survey.

Respondents' Current Vehicles

The survey findings on current vehicles are consistent with the aggregate findings of DMV and ACS data analysis. Chapter 7 contains details of the current vehicle holdings of the residential and commercial light duty fleets.

About 73 percent of the residential ZEV owners in the survey had only one vehicle, and about 22 percent of the two plus vehicle ZEV households owned 2 ZEVs, with only 7 percent of 3 plus households owning 3-5 ZEVs. In contrast, 85 percent of ZEV owners in commercial survey owned only one ZEV, 11 percent of the two plus vehicle fleet owners had 2 ZEVs and 8 percent of three plus fleet sizes owned 3-5 ZEVs.

Autonomous Vehicles

New transportation technologies are more favored by ZEV owners and those who have experience with the new technology. While ride hailing is no longer a new technology, its use and frequency vary across the state. But, overall, 61 percent of residential survey participants have used ride-hailing less than once a month, and only 4 percent used it 3-4 times a week.

Commercially owned self-driving, or fully autonomous, vehicles are being used for ride-hailing in select California cities. There are five levels of autonomy used for classifying AVs, with level five being considered fully autonomous, with no need for a driver in the car. However, a significant portion of new vehicles in the market already include level one and level two AV features. Autonomous vehicle levels one and two have features such as parking assistance and front collision warning. Only 21 percent of the respondents had no experience with any of those AV features, while the rest had experience with one or more of those features. The participants living in San Francisco and Los Angeles areas had more experience of riding in an AV, had more positive attitudes toward AVs, and were more likely to say they would be early adopters of personal AVs. ZEV owners also had more positive attitudes toward AVs and were much more likely to say that they would be early adopters of AVs, with 28 percent of ZEV owners saying they would be early adopters in contrast with only 9 percent of the non-ZEV owners.

While 14 percent of respondents said that they would be "one of the first to buy" an AV, only 7 percent of the participants said they would send their empty AV to pick up their children. Only 14 percent of the respondents said they would own fewer vehicles if they had an AV, while the rest said they would not change the number of vehicles they own.

Only 5 percent of commercial fleet owners had no awareness of AV technology. The rest were aware of the technology as expected. About 35 percent did not see the need for self-driving vehicles. Like the residential participants, the commercial fleet owners who owned ZEV vehicles had more positive attitudes toward AVs.

Generally, high variation among respondents' preferences for AVs did not lead to any statistically significant preferences for any of AV Levels 3-5. This may also be the result of respondents' poor differentiation between different levels of autonomy. However, when the reference vehicle in the AV discrete choice experiment was a BEV, the estimated effect of increasing levels of autonomy on respondents' utility was positive and statistically significant.

This suggests that among the subset of both residential and commercial respondents who say they would purchase a BEV, they might also be interested in AV technologies for BEVs.

Vehicle-to-grid technology

Among the residential survey respondents, 66 percent lived in single-family units, and 53 percent had an attached garage where they parked their cars. A higher percentage of EV owners lived in SFU, and 59 percent of PEV owners had access to 240-volt outlets where they parked their car.

Households with plug-in electric vehicles (PEVs) are more likely to have rooftop solar energy. About 45 percent of PEV owners had solar energy, whereas 22 percent of non-PEV households had solar energy. Residential BEV owners are also more likely to adopt battery storage, with about 28 percent who have already installed battery storage and an additional 33 percent who are planning to install one. Among the commercial survey respondents, 17 percent had rooftop solar with battery storage, as backup energy, and 11 percent had solar panels only.

While 48 percent of the respondents had no awareness of vehicle to grid technology, only 4 percent said that they have used it. If they were paid for it, 54 percent said they may participate in vehicle to grid integration, and 29 percent said they would not participate in such program.

About 39 percent of respondents said they would be more likely to buy an EV if they are paid to discharge their vehicle's battery into the public grid or to supply power to their house in the event of an outage. The main concern that would lower participation (for 54 percent of the participants) in V2G was the potential to increase wear on the vehicle's battery and shorten the battery replacement timeline.

The Factors Current and Future Vehicle Owners Consider when Purchasing a New Vehicle

The survey identifies respondents' "revealed preferences" and "stated preferences." Current vehicles owned by households and businesses reveal the car purchaser's preferences in the survey. The revealed preference survey data indicates factors affecting current vehicle ownership. For example, consumers with higher incomes are significantly more likely to buy new vehicles. Stated preferences refer to the stated future vehicles that respondents choose from a set of hypothetical vehicle options in the survey's choice experiments. Stated preference survey data allow for assessment of the factors that are important to the choice of future vehicle technologies, which are used to forecast new vehicle sales.

Comparing different vehicle attributes, vehicle price had the most significant impact on vehicle choice. Price was even more important to the commercial vehicle buyers, followed by maintenance and fuel costs. The impact of prices on residential vehicle choice is higher at lower levels of income. Maintenance and fuel costs also have a statistically significant impact on household vehicle choice. So, a decline in ZEV prices relative to non-ZEV vehicles will increase the likelihood of buying ZEV vehicles.

Households showed higher preferences for midsize cross-over SUV and pickup trucks, followed by large SUVs. Commercial fleet owners showed the highest preference for pickup trucks, followed by vans and SUVs.

Policy measures, such as government vehicle incentives, have a significant impact on the likelihood of buying ZEV vehicles. Among the three vehicle incentives presented in the survey, the Federal tax credit had the most significant and consistent impact in both residential and commercial sectors.

Overall commercial fleet owners prefer gasoline to other fuel types, but as expected, industry groupings dealing more with office activities, such as health and education, show higher preferences for ZEVs compared to industries more focused on heavy industrial, construction, agriculture, and mining.

Households and commercial fleet owners that currently own a ZEV vehicle are more likely to buy another ZEV for their next vehicle.

Recommendations for Future Research

In designing, implementing, and analyzing the data for the 2024 survey, RSG developed the following recommendations for future iterations of the survey:

- Survey response rates were considerably lower than past iterations of the survey, so RSG recommends anticipating no higher than a 2.5 percent response rate among residential respondents.
- The 2024 survey included a novel discrete choice experiment for autonomous vehicle choice. While these experiments did yield interesting results, the model results suggested that participants had unreliable preferences about autonomous vehicle technology and were strongly opposed to purchasing such vehicles. Future iterations of the survey could include autonomous vehicle choice questions in the following ways:
    - **As an attribute of battery electric vehicles in the vehicle type discrete choice experiment.** By the time the next California Vehicle Survey is administered, respondents may be more familiar with the concept of personally owned autonomous vehicles. Because these vehicles are not available alternatives in the vehicle market, respondents may have struggled to value the respective levels of autonomy.
    - **As an attribute of a choice for vehicle quantity or transaction and replacement models.** Because autonomous vehicles are most familiar to participants as ride-hailing services rather than personal vehicles, access to these sorts of ride-hailing services might influence people’s likelihood of replacing vehicles or owning more vehicles.
    - **As an attribute in a novel transportation mode choice model.** Autonomous ride hailing is likely to become more widespread in coming years. Because of this, demand for these services and the vehicle charging infrastructure that supports them might be more fruitfully modeled in a mode choice rather than a vehicle choice model.

CHAPTER 1: Introduction

The California Energy Commission is directed by Public Resources Code (PRC) Section 25301 to conduct assessments and forecasts of all aspects of energy industry supply, production, transportation, delivery and distribution, demand, and prices. The Energy Commission uses these assessments and forecasts to develop and adopt an Integrated Energy Policy Report (IEPR) every two years. The IEPR includes an overview of major energy trends and issues facing the state, including, but not limited to, supply, demand, pricing, reliability, efficiency, and impacts on public health and safety, the economy, resources, and the environment. To support the IEPR, the Energy Commission is directed to conduct transportation forecasting and assessment activities, including, but not limited to:

- The assessment of trends in transportation fuels, technologies, infrastructure supply, demand, and the outlook for wholesale and retail prices for petroleum and alternative transportation energy under the current market structures and the expected market conditions.
- Forecasts of statewide and regional transportation energy demand, annual and seasonal, and the factors leading to projected demand growth, including projected population growth; urban development; vehicle miles traveled; the type, class, and efficiency of personal vehicles and commercial fleets; and the shifts in transportation modes.
- Evaluation of the sufficiency of transportation fuel supplies, technologies, and infrastructure to meet projected transportation growth in demand.
- Evaluation of alternative transportation energy scenarios, in the context of least environmental and economic costs, to examine potential effects of alternative fuels usage, vehicle efficiency improvements, and shifts in transportation modes on public health and safety, the economy, resources, the environment, and energy security.
- Examination of the success of introduction, prices, and availability of advanced transportation technologies, low- or zero-emission vehicles, and clean-burning transportation fuels, including related potential future contributions to air quality, energy security, and other public interest benefits.
- Recommendations to improve the efficiency of transportation energy use, reduce dependence on petroleum fuels, decrease environmental impacts from transportation energy use, and contribute to reducing congestion, promoting economic development, and enhancing energy diversity and security.

The Energy Commission prepares the forecast and assessment of transportation energy demand, the outlook for retail fuel prices, and the analysis of shifts in fuel types, vehicle types, and other factors based on analysis of data collected from different sources. One source of data is the California Vehicle Survey (CVS), a survey that has been conducted periodically over the past three decades to assess current vehicle ownership, preferences, and use. The Energy Commission uses the light-duty vehicle (LDV) choice models that are based on the CVS data to assess current vehicle ownership, the factors that current and future vehicle owners consider when purchasing a new vehicle, and the likelihood that they would purchase an alternative fuel vehicle or other advanced technology vehicle. Changes in the market conditions, consumer awareness, and technology and manufacturer offerings result in changes in consumer preferences. Repeating the survey allows the Energy Commission to capture the shifts in consumer preferences and improve the accuracy of forecasts.

The CVS has been conducted periodically since the late 1990s and has been updated over time as vehicle technology and consumer preferences evolve. Beginning in 2016, the CVS included an additional targeted sample of plug-in electric vehicle (PHEV) owners to supplement the general residential and commercial fleet owner samples. This survey also included questions on solar panel ownership for the first time. The 2019 CVS was built upon the previous surveys to update consumer preferences and added targeted samples of the zero-emission vehicle (ZEV) owners to learn about both their preferences and their vehicle use and charging behavior.

The 2019 survey also added questions to assess attitudes toward autonomous vehicles (AV). The 2024 CVS maintained a targeted sample of ZEV owners in both residential and commercial market segments and added questions on backup power sources and potential vehicle-to-grid (V2G) preferences and behavior. Additionally, the 2024 survey includes a separate set of discrete choice experiments related to AV technology preferences.

Project Goals

The goals of the CVS are to design, and conduct revealed preference (RP) and stated preference (SP) surveys for the household/residential LDV and the commercial LDV market segments. The survey results are used to update LDV choice models that are used in generating the LDV population and fuel demand forecast for the Integrated Energy Policy Report (IEPR).

The LDV choice models are designed around levels of vehicle ownership: three categories of vehicle holdings for households and five categories of fleet size for businesses. The surveys represent California households and California businesses in each of these categories.

In addition to the CEC's Energy Assessments Division (EAD), the CEC's Fuels and Transportation Division (FTD) and the California Department of Transportation (Caltrans) cosponsored the survey project, and EAD managed the survey. The intra- and interagency project collaboration started before the solicitation process, in 2023, with California Air Resources Board (CARB), Caltrans, and FTD staff participating in the questionnaire design process. Resource Systems Group, Inc. (RSG) was selected through the competitive solicitation process to design and execute the survey.

The survey work is presented in two volumes. Volume 1, this report, describes different processes, methods and instruments used in the two phases of the survey, in the following chapters:

- Survey design
- Focus group design and analysis
- Survey pretest design and analysis
- Main survey implementation
- Main survey results

- Modeling results

Volume 2 includes appendices that contain the details of design, the actual survey questionnaires, experimental design, survey web pages, and survey material.

Changes in the 2024 Survey

RSG reviewed and compared the two most recent versions of the household questionnaires, from the 2016 CVS and the 2019 CVS, and used them as the starting point for the 2024 survey.

While the information collected in the 2024 residential questionnaire is largely consistent with previous versions of the survey, the question flow, layout, and formatting were updated to make the survey more efficient and easier to complete online. One key difference between the 2024 survey and previous versions was the inclusion of questions related to AVs as well as vehicle-to-grid technology.

In the 2024 CVS, respondents could complete the RP and SP survey components in a single session. As a result, separate recruiting and follow-up mailing efforts, which had been employed in iterations prior to 2016, were not required. Respondents began the survey by completing a series of RP questions about their household composition and household vehicle characteristics. This information was used to generate a set of realistic discrete choice experiments in real time as the respondents progressed through the survey. The 2024 CVS used two SP instruments: one for LDV type choice, as in the past, and the second one specific to personal AV choice.

The survey design and implementation are described in more detail in the following chapters.

CHAPTER 2: Website and Database Design

The 2024 CVS collected both RP and SP information for the residential and commercial LDV market segments in California, as well as an add-on survey for respondents who own or lease ZEVs. The surveys were completed using a web-based retrieval instrument. A key component of the CVS is the public-facing project website, which provides information about the project and associated sponsors, instructions for participating in the study, answers to frequently asked questions, privacy information, and access to the survey instruments.

Survey Website

Invited households were instructed to go to the CVS project website and enter their unique password and complete the survey using the online instrument. Participants who stopped midway through the survey and returned later were able to resume the survey at the question they last answered.

RSG partnered with Jibunu, a firm that specializes in online survey programming, to develop the project website and survey instruments. Jibunu's proprietary architecture uses the most current technologies to protect data during and after data collection (for example, encryption of all submitted data over the Internet) to ensure proper consideration of all data privacy concerns and continuous "uptime" of all technology. The website was designed to render properly on computers, tablets, and smartphones, which is important given the increasing share of participants who take surveys on mobile devices.

A few examples of how the survey instrument ensured data consistency and minimized respondent burden include the following:

1. Each respondent used the survey interface to ensure that all data undergo the same logic, validation, and real-time checks to reduce respondent burden and error.
2. Metadata collection (as determined by the CEC) permits passive collection of data such as survey duration (in total and by each question), screen resolution, and browser type (for example, Edge, Chrome, Safari, or Firefox), default language of web browser, and more. These data can be used to compare participants to the overall population and identify trends and ensure that the survey instrument accommodates all users.
3. All respondents could complete the RP and SP surveys at the same session, minimizing respondent burden and drop-off between the surveys.
4. The survey was provided in English and Spanish for residential respondents.
5. Complex logic checks were built into the survey software to avoid illogical responses at the household, person, company, and vehicle levels. For example, real-time checks were made to identify combinations of vehicle make/model and fuel type that are not actually available in the market, and respondents were asked to reconsider or clarify those responses (for example, an after-market fuel type conversion was done on the vehicle).

The 2024 survey included two sets of discrete choice experiments. The first (vehicle type choice) focused on consumer preferences related to vehicle class and fuel type. The second (AV choice) focused on consumer preferences for different levels of AV technology. In both cases, the RP data were used in real time to develop discrete choice experiments that were customized for each respondent. Similarly, the vehicle type choice data were used to feed into and inform the AV discrete choice.

In the 2024 CVS, a survey response was defined as complete when the respondent provided an answer for each data element in the survey. Because the online instrument was designed to fully integrate the RP and SP surveys, the surveys were considered complete only when respondents completed both survey components. Because the survey data were entered into and validated in real time using the survey website, there was no missing data or item nonresponse. Participating respondents who exited the survey without completing each question were not included in the tally for sample size goals. However, their partial responses were still recorded. Respondents who started the survey and dropped out were recontacted by email to encourage them to complete the survey and provided with help navigating the survey instrument, if necessary.

The completed survey instrument was extensively tested by multiple internal and external clients, including staff at the CEC, Caltrans, and CARB, in an environment that mimics actual data collection.

Screenshots from the project website are provided in "Appendix A: Survey Website Screenshots." The website content was translated into Spanish after the English version was reviewed and finalized in coordination with the commission agreement manager, for residential participants who chose to complete the survey in Spanish.

Database Design

The survey database was developed at the same time as the online survey instrument described above. The survey database was hosted on Amazon Web Services Aurora, a secure, enterprise-level, cloud-based SQL environment that provides near-100 percent uptime and scalability to meet fluctuating server demand. The survey website interacted directly with the database, and all responses were input directly by respondents using the survey website in real time.

A survey dashboard provided data on the number of complete residential and commercial vehicle surveys, select tabulations, and other custom information requested by the CEC. The dashboard was available via a password-protected page on the survey website that was accessible only to the client. For the duration of data collection, the dashboard showed the number and percentage of completed surveys obtained along various dimensions, including:

- Geographic area.
- Household income (detailed and broad categories, including refusals).
- Household size.
- Household workers.
- Age category of head of household.
- Race/ethnicity, including refusals.

- Number of vehicles owned.
- Vehicle body type and fuel type (including ZEVs).

Similar data were available for the commercial survey during data collection, but with somewhat different categories, such as:

- Geographic area.
- Commercial sector (based on North American Industry Classification System)
- Company size category.
- Fleet size category.
- Vehicle class/type and fuel type (including ZEVs).

The dashboard was monitored daily during the data collection phase to compare survey responses to sample targets.

CHAPTER 3: Survey Design

This chapter summarizes work done to design the 2023–2024 CVS questionnaires. The first section of the chapter discusses the survey questionnaire design for the residential survey, and the second section of the chapter discusses the survey questionnaire design for the commercial survey.

Residential Vehicle Survey Questionnaire and Instrument

The project team began by reviewing and comparing the most recent iteration of the CVS, including the 2016 and 2019 residential CVS questionnaires. These documents were used as the starting point for the 2024 survey.

While the information collected in the 2024 residential questionnaire is largely consistent with previous versions of the survey, the question flow, layout, and formatting were updated to make the survey more efficient and easier to complete online. One key difference between the 2024 survey and previous versions was the inclusion of questions related to autonomous vehicles, as well as household backup battery ownership and V2G technology.

In the 2024 CVS, respondents could complete the RP and SP survey components in a single session. As a result, separate recruiting and follow-up mailing efforts were not required. Respondents began the survey by completing a series of RP questions about their household composition and household vehicle characteristics, as well as the vehicle(s) they consider for purchase in future. This information was used to generate a set of realistic discrete choice experiments in real time as the respondents progressed through the survey. The responses to discrete choice experiments embody respondent's stated preferences.

The choice experiments appeared directly following the RP questions, with no observable differentiation in the survey experience from the perspective of respondents. An additional discrete choice experiment section was included to test willingness to pay for higher levels of vehicle autonomy.

The final residential survey questionnaire was translated into Spanish, and respondents had the option of completing the survey in English or Spanish, as preferred. The residential vehicle questionnaire is included in "Appendix B: Survey Questionnaires."

The following sections describe the contents of the survey questionnaire, grouped by topic into sections.

Section 1: Survey Introduction

The survey introduction consisted of three main components: a welcome message, password verification, and survey instructions. The welcome message provided an overview of the survey, associated sponsors, purpose, and data confidentiality. It also included information related to the estimated completion time of 30 minutes, the participation incentive of a $15 digital gift card, and instructions for navigating the survey instrument.

Section 2: Survey Qualification

The survey qualification questions ensured participant eligibility, including criteria such as the respondent's age (must be 18 or older), California residency status (defined as living in California for at least six months per year and holding a California driver's license or ID), and specific location within the state (via ZIP code and county). In addition, it assessed the respondent's role in future vehicle purchase decisions, targeting those who will be primary or equal decision-makers. The survey also gauged current vehicle ownership and intent to purchase a vehicle within the next five years. Respondents who did not meet the eligibility criteria were disqualified from continuing in the survey.

Section 3: Current Vehicle(s)

The current vehicle section of the survey gathered comprehensive data about respondents' household vehicles. This section began by asking about the total number of vehicles in the household, followed by detailed information about each vehicle. Respondents provided specifics such as the vehicle model year, make, model, fuel type, and vehicle class. The survey also asked about how the vehicle was obtained and, in the case of company cars, whether a household member influenced the purchase decision. This section also collected data on vehicle mileage, annual vehicle miles traveled (VMT), the primary driver, and vehicle replacement expectations.

Section 4: Household Members

This section of questions collected detailed information about respondent’s household composition, including the number of members in different age groups (under 5, 5–11, 12–15, and 16 or older). For each household member aged 16 or older, the survey requested initials or nicknames, age ranges, and relationships to the primary respondent.

Respondents were then asked to provide more detailed demographic and travel behavior information for each household member aged 16 or older. This information included topics such as gender, race/ethnicity, employment status, education level, driver's license possession, and driving frequency. It asked about travel behavior including public transit usage, ridesharing frequency, and commuting patterns for work or school. It also captured important details such as primary work location, commute distance, and preferred commute mode.

Section 5: Alternative Fuel Vehicle Consideration

This section assessed respondents' familiarity with and attitudes toward various types of alternative fuel vehicles. It explored past experiences with hybrid electric vehicles (HEV), plug-in hybrid vehicles (PHEVs), battery-electric vehicles (BEVs), and hydrogen fuel cell electric vehicles (FCEVs). It asked whether households have owned or leased these vehicle types and, if not, their level of familiarity with them. The survey also probed awareness of electric vehicle public charging infrastructure and hydrogen fueling stations.

Section 6: BEV and PHEV Owner Questions

Respondents who reported owning a plug-in electric vehicle, including PHEVs and BEVs, were asked to provide information about various aspects of plug-in vehicle ownership, including charging access and behavior, vehicle usage patterns, charging costs, and overall satisfaction.

The survey asked about factors such as the electric range of the vehicle on a full charge, typical charging schedules, home charging capabilities and equipment, and home electricity rates for charging. Questions about public charging use included the frequency of public charging, cost, any issues encountered and the importance of various incentives in the decision to adopt these technologies.

Respondents were asked about their interest in vehicle-to-home (V2H) technology to avoid peak-period electricity rates, power their home during a power outage, or be reimbursed for discharging the car battery into the electrical grid.

Finally, respondents were asked about their overall experience with their plug-in vehicle, and specifically their experience with charging their plug-in vehicle.

Section 7: FCEV Owner Questions

Like the plug-in electric vehicle questions, the FCEV section of the survey focused on gathering detailed information about the ownership experience and usage patterns of hydrogen fuel cell vehicles. The questions covered a wide range of topics, including refueling frequency, refueling behavior, station availability and convenience, waiting times, and the maximum distances traveled to refuel. It also explored how FCEV owners adapt when hydrogen stations are not available.

Furthermore, the survey gauged overall satisfaction with the fueling experience, the likelihood of recommending FCEVs to others, and the importance of various incentives in the decision to adopt FCEV.

Section 8: Next Vehicle Purchase Details

This section asked respondents about their vehicle purchase intentions and preferences. It began by asking respondents about their next vehicle purchase or lease, including whether it will be a replacement for an existing vehicle or an additional vehicle for their household. It then explored the expected timing of this purchase, with options ranging from less than a year to more than 10 years in the future. The survey asked respondents to provide up to four vehicle types that they would consider for their next purchase. For each vehicle type, respondents were then asked to select up to four from seven fuel types (for example, gasoline, HEV, PHEV, BEV, and so forth) that they would consider purchasing/lease. For each vehicle type/fuel type combination, respondents were then asked to indicate if they would consider new or used vehicles and standard or premium brands for each option.

This information was used to build a vehicle consideration set for each respondent, which was then used to customize the vehicle alternatives presented in the vehicle type discrete choice experiments.

Section 9: Vehicle Type Discrete Choice Experiments

This set of questions employed a discrete choice experiment method to understand consumer preferences and decision-making processes related to vehicle choice. Respondents were presented with eight choice scenarios consisting of four hypothetical vehicle alternatives. The four vehicles in each exercise were described by a set of up to 16 attributes, including the vehicle type, fuel type, purchase price, fuel efficiency, range, and other relevant characteristics that influence vehicle choice. Respondents were asked to select the vehicle they would most prefer to purchase under the conditions presented.

A statistical experimental design was used to vary the vehicle attributes from experiment to experiment in a controlled manner. In this way, the data collected from these experiments can be used to develop discrete choice models to support forecasts of vehicle fleet composition.

The design and implementation of the discrete choice experiments are described in "Appendix C: Discrete Choice Experiment Design."

Section 10: Autonomous Vehicle Discrete Choice Experiments

After the vehicle type discrete choice experiments, respondents were presented with a second set of discrete choice experiments focusing on vehicle autonomy technology. These experiments built upon the previous vehicle type discrete choice experiments by introducing autonomous features as an additional option for vehicles that respondents expressed interest in purchasing. By presenting different levels of autonomy with associated costs, the survey aimed to gauge the perceived value and acceptance of these advanced technologies among potential buyers.

Because the AV discrete choice experiments were kept separate from the larger vehicle choice discrete choice experiments, the levels of autonomy cannot be modeled as a distinct attribute of a vehicle that is comparable to the other attributes in the vehicle type choice experiments. Instead, the survey team opted to have respondents choose a level of autonomy independent of other vehicle attributes. This staged approach to the AV choice experiment is advantageous for the following reasons:

- Because vehicle autonomy is a relatively novel vehicle attribute, this staged approach allowed respondents to make a distinct choice about autonomy level without this choice being confounded by other vehicle attributes.
- By separating vehicle autonomy from other vehicle attributes, the data from this experiment can then be linked back to the full discrete choice experiment (DCE) data with the price attribute.
- A joint model can be estimated in which the constants in the AV vehicle choice component represent the effect of each level of autonomy on respondents' utility.

Respondents were presented with four experiments consisting of four vehicle alternatives that reflected different prices for different levels of autonomy (SAE Levels 2, 3, 4, and 5). Respondents were asked to select the vehicle they most preferred under the conditions presented.

The AV discrete choice experiments are described in more detail in "Appendix C: Discrete Choice Experiment Design."

Section 11: Dwelling Information

Following the discrete choice experiments, respondents were asked to provide information about their dwelling. This section covered a wide range of topics, including respondents' type of housing (for example, single-family home, apartment), parking options available at home, access to electricity for potential EV charging, and the presence of solar panels or backup power systems. It also gauged awareness and interest in vehicle-to-grid (V2G) technology, exploring how this emerging technology might influence EV purchasing decisions.

Section 12: Household Income and Contact Information

Before completing the survey, respondents were asked to identify their annual household income from a range of options, spanning from low-income brackets (for example, "Less than $9,999") to high-income brackets (for example, "$250,000 or more"). Because vehicle choice and use are correlated with income, these data are necessary to support the development of the discrete choice models from the survey data.

Finally, respondents were given the opportunity to provide an email address to receive their participation incentive and were asked if they would be willing to participate in a follow-up survey at a later date. Respondents were also given the opportunity to provide open-ended comments about topics covered in the survey or the survey itself.

Commercial Establishment Survey Questionnaire and Instrument

The commercial establishment questionnaire followed the same general structure as the residential questionnaire. The 2016 and 2019 Commercial CVS questionnaires were used as the starting point for the 2024 survey. The question flow and formatting were both revised for efficiency and consistency with the residential survey while preserving the survey information content. The commercial survey — like the residential survey — could be completed in a single sitting without recontacting for the discrete choice experiment component. From the respondent's perspective, there was no differentiation between the RP and SP survey components when completing the questionnaire.

The commercial fleet owner survey also included a set of questions specific to ZEV owners, a set of questions related to autonomous vehicles, a set of questions relating to vehicle-to-grid technology, and an additional discrete choice experiment section about autonomous vehicles as described in the residential survey section.

The commercial vehicle questionnaire is included in "Appendix B: Survey Questionnaires."

The following sections describe the contents of the survey questionnaire, grouped by topic into sections.

Section 1: Survey Introduction

The introduction for the commercial survey consisted of three main components: a welcome message, password verification, and survey instructions. These are very similar to the residential survey. The welcome message provided an overview of the survey, associated sponsors, purpose, and data confidentiality. It also included information related to the estimated completion time of 30 minutes, the participation incentive of a $40 digital gift card, and instructions for navigating the survey instrument.

Section 2: Survey Qualification

The survey's qualification questions ensured eligibility for the commercial survey. It included questions about the respondents' familiarity with their organization's vehicles and decision-making processes, as well as the type of organization they represent. The survey also ensured that vehicles were used for commercial purposes at least 50 percent of the time, and that they did not represent car rental companies, taxicab companies, or government agencies, which are not the target audience for this study.

Section 3: Company Information

This section of the survey gathered details about respondents' organization. It included questions about the respondent's title or role, the number of business locations operated by the organization in California, how many of these locations have light-duty vehicles, and the number of employees at the respondent's specific location. It also collected data on vehicle services used, such as ride-hailing, ridesharing, or courier services.

Section 4: Fleet Information

This section of the survey collected information about the organization's existing commercial vehicles, including the number and types of vehicles in their fleet, the fuel types of those vehicles, and the AV features of their fleet.

Section 5: Refueling Capabilities

This section of the survey focused on understanding the current and potential future refueling infrastructure available to commercial vehicle fleets. It explored the availability of dedicated parking facilities, existing on-site refueling capabilities, and the potential for installing new refueling options in the future. It also asked about backup energy sources and battery storage devices, which are becoming increasingly important in the context of grid resilience and energy management.

The survey collected information about on-site refueling systems, including the types of fuel available (gasoline, diesel, hydrogen) and electric vehicle charging options (Level 1, Level 2, DC fast charging). It also asked about plans to install additional fueling capabilities and the consideration of costs associated with these installations.

Section 6: Alternative Fuel Vehicle Consideration

This section of the survey assessed respondents' familiarity with and attitudes toward various types of alternative fuel vehicles, including HEVs, PHEVs, BEVs, and FCEVs. It explored whether companies have owned, leased, or considered purchasing these vehicle types. It also evaluated respondents past experiences with these technologies, ranging from direct ownership to merely noticing them in their community. The survey further probed awareness of electric vehicle public charging infrastructure and hydrogen fueling stations.

Section 7: BEV and PHEV Owner Questions

Respondents who reported owning a plug-in electric vehicle, including PHEVs and BEVs, were asked to provide information about various aspects of plug-in vehicle ownership. This included information such as charging locations (on-site vs. off-site), charging frequency, charging times, electricity rates, and overall satisfaction with these vehicles.

Commercial respondents were asked about their interest in vehicle-to-home (V2H) technology to avoid peak period electricity rates, power their business location during a power outage, or be reimbursed for discharging the car battery into the electrical grid.

Finally, respondents were asked about their overall experience with their plug-in vehicle and, specifically, their experience with charging their plug-in vehicle. It also explored the importance of various incentives in the decision to adopt these technologies.

Section 8: FCEV Owner Questions

The FCEV section of the survey focused on the experiences and usage patterns of businesses that have adopted FCEVs. This section covered aspects such as refueling locations, frequency, costs, and overall satisfaction with FCEVs. It also explored the importance of various incentives in the decision to adopt this technology and the reasons behind choosing FCEVs over other alternatives.

Section 9: Next Vehicle Purchase Details

This section asked respondents about their vehicle purchase intentions and preferences. It began by asking respondents about their next vehicle purchase or lease, including whether it will be a replacement for an existing fleet vehicle or an additional vehicle for the company fleet. It then explored the expected timing of this purchase, with options ranging from less than a year to more than 10 years in the future. The survey asked respondents to provide up to four vehicle types that they would consider for their next purchase. For each vehicle type, respondents were then asked to select from seven fuel types (e.g., gasoline, hybrid electric vehicle, plug-in hybrid electric vehicle, battery-electric vehicle, etc.) that they would consider. For each vehicle type/fuel type combination, respondents were then asked to indicate if they would consider new or used vehicles and standard or premium brands for each option.

This information was used to build a vehicle consideration set for each respondent, which was then used to customize the vehicle alternatives presented in the vehicle type discrete choice experiments.

Section 10: Vehicle Type Discrete Choice Experiments

This set of questions employed a discrete choice experiment methodology to understand consumer preferences and decision-making processes related to vehicle choice. Respondents were presented with eight choice scenarios consisting of four hypothetical vehicle alternatives. The four vehicles in each exercise were described by a set of up to 16 attributes, including the vehicle type, fuel type, purchase price, fuel efficiency, range, and other relevant characteristics that influence vehicle choice. Respondents were then asked to select the vehicle they would most prefer to purchase under the conditions presented.

A statistical experimental design was used to vary the vehicle attributes from experiment to experiment in a controlled manner. In this way, the data collected from these experiments can be used to develop discrete choice models to support forecasts of vehicle fleet composition.

The design and implementation of the discrete choice experiments are described in more detail in "Appendix C: Discrete Choice Experiment Design."

Section 11: Autonomous Vehicle Discrete Choice Experiments

As in the residential questionnaire, commercial respondents were presented with a second set of four discrete choice experiments focusing on vehicle autonomy technology. These experiments built upon the previous vehicle type discrete choice experiments by introducing autonomous features as additional options, with associated incremental price, for vehicles that respondents selected to purchase/lease in prior vehicle type choice experiments. By presenting different levels of autonomy with associated costs, the survey aimed to gauge the perceived value and acceptance of these advanced technologies among potential buyers.

Respondents were presented with four experiments consisting of four vehicle alternatives that reflected different prices for different levels of autonomy (SAE Levels 2, 3, 4, and 5). Respondents were asked to select the vehicle they most preferred under the conditions presented.

The AV discrete choice experiments are described in more detail in "Appendix C: Discrete Choice Experiment Design."

Section 12: Incentive and Contact Information

This section served as the concluding part of the commercial survey, addressing the reward for participation and gathering contact information for future engagement. The survey offered respondents a $40 electronic gift card to either Walmart or Amazon as a reward for their participation. Respondents were also given the opportunity to provide open-ended comments about topics covered in the survey or the survey itself.

CHAPTER 4: Focus Groups

Focus groups help researchers gain insights into different survey topics and elements. Focus groups are particularly important to the 2024 CVS, as the survey covers new topics such as vehicle-to-grid preferences and autonomous vehicle choice experiments. The insights gained from the focus groups were used to inform the pretest survey language, questions, and design.

Design and Methodology

The project team conducted nine focus group sessions between February 5, and February 9, 2024, in four regions of California: San Francisco, Sacramento, Fresno, and Los Angeles. The focus groups were designed to cover four segments of LDV owners in California:

1. Residential vehicle owners
2. Residential ZEV owners
3. Commercial business owners or fleet managers with LDVs
4. Commercial business owners or fleet managers with at least one light-duty ZEVs in the fleet

Residential and commercial group sessions were conducted in each of the four regions as described in **Table 1**. The residential group in Fresno was conducted in Spanish to identify potential language barriers related to the survey questions or vehicle definitions and support the Spanish language survey. A single ZEV owner focus group session was conducted in Los Angeles, since the region has the largest share of the California ZEV market, including residential and commercial ZEV owners.

Table 1: Focus Group Locations and Schedule

Focus Group Date	Focus Group Location	Type of Group	Number of Participants
February 5, 2024	San Francisco	Residential	8
February 5, 2024	San Francisco	Commercial	6
February 6, 2024	Sacramento	Residential	9
February 6, 2024	Sacramento	Commercial	8
February 7, 2024	Fresno	Residential (Spanish)	7
February 7, 2024	Fresno	Commercial	8
February 9, 2024	Los Angeles	Commercial	8
February 9, 2024	Los Angeles	Residential	9
February 9, 2024	Los Angeles	Commercial and Residential ZEV Owners	10

Source: 2024 California Vehicle Survey, California Energy Commission

Recruitment

The focus group sessions were conducted at different professional focus group facilities in each region. The facilities used telephone-based outreach to identify and screen potential participants through the use of a screening and eligibility questionnaire (screener) developed by RSG. Separate screeners were developed for residential, commercial, and ZEV owner participants, and recruiters in each city used the screeners to identify individuals willing to participate in the groups. The facilities recruited at least 10 participants for each group with the goal of having 8–10 individuals participate.

Participants for the residential groups were screened by age, gender, level of education, and household income, with a goal of having diverse demographic representation in each group. Participants must also at least share some responsibility for vehicle purchase or lease decisions in their household. The recruitment firm in each city provided participant demographic data to RSG and the CEC after removing personal identifying information such as last names, phone numbers, and addresses. The specific recruiting guidelines for each type of focus group are defined in more detail below.

Residential Recruiting Guidelines

The residential focus group recruiting guidelines focused on the following characteristics:

- Obtain a representative mix of income/age/gender/race/household size, but all participants must be at least 18 years old.
- No more than one unemployed participant. Non-working respondents should not be a disproportionate share of the group.
- Recruit respondents owning/leasing a range of vehicle types, makes, and models (including electric vehicles) broadly representative of the local area.
- Most respondents should either have purchased/leased or intend to purchase/lease a new vehicle; it is acceptable to include some respondents who have purchased/leased or intend to purchase/lease a used vehicle.
- For the San Francisco and Los Angeles regions: At least one respondent should have solar panels at their house.
- For the Fresno region: All focus group participants must primarily speak Spanish at home, and this session will be conducted entirely in Spanish.

Commercial Recruiting Guidelines

The commercial focus group recruiting guidelines focused on the following characteristics:

- Target employees of businesses which own and operate commercial vehicles.
- Employees must be responsible for making commercial vehicle/vehicle fleet purchase decisions.
- Include businesses with a mix of vehicle types and fuel types in their fleet.
- Include a mix of industries, but exclude government agencies, rental car services, and automobile manufacturers and dealers.
- Include mix of fleet sizes.

ZEV Recruiting Guidelines

The ZEV focus group recruiting guidelines focused on the following characteristics:

- Obtain a representative mix of income/age/gender/race/household size, but all participants must be at least 18 years old.
- All participants must be current BEV/PHEV/FCEV owners or commercial fleet owners with fleets that include BEV/PHEV/FCEV.
- Obtain a mix of occupations that are broadly representative of the local region.
- Recruit commercial respondents owning/leasing a range of fleet sizes, vehicle types, make and models broadly representative of the local region.
- Recruit no more than five and no fewer than three commercial participants.
- Recruit no more than seven and no fewer than five residential participants.
- Obtain a mix of charger types and number of miles driven.
- Recruit one hydrogen fuel cell driver in either the commercial or residential sector.

Moderation

Each focus group lasted about two hours. A moderator in each group addressed the topics and questions of interest using a structured moderator guide, with some flexibility allowed for participants to alter the direction of the discussion, where appropriate.

Each focus group began with an explanation of the purpose of the session and a brief overview of the ground rules. Participants were informed that they were being recorded and observed by staff from the CEC through a two-way mirror.

Following the overview from the moderator, participants were asked to introduce themselves and provide information about their vehicle ownership and usage (including the number and types of vehicles in their household), whether they own or lease their vehicles, and how they used their vehicles.

All focus group sessions were conducted using a structured moderator guide developed by RSG and the Energy Commission. The guide reflected the standard focus group practice of moving from general topics to more specific topics, and included the following:

- Welcome/ground rules
- Current vehicles and driving habits
- Future car purchase needs and desired attributes
- Alternative fuel and powertrain knowledge and perceptions. For this portion of the conversation, the moderator prompted discussion of the following fuel types:
  - Diesel vehicle (commercial only)
  - Hybrid electric vehicle (HEV)
  - Plug-in hybrid electric vehicle (PHEV)
  - Battery-electric vehicle (BEV)
  - Hydrogen fuel cell electric vehicle (FCEV)
- Autonomous vehicles feature knowledge and perceptions

- CVS discrete choice experiments review, in which participants were given an example set of vehicle type discrete choice experiments and a set of AV discrete choice experiments and asked to report their experiences completing the experiments

Incentives

Participants received a monetary incentive after each focus group session. Residential participants received between $150 and $200 and commercial participants received between $200 and $250, depending on location.

Analysis

The discussions and outcomes of all groups are summarized in this report. It is important to note that, as with all qualitative research, the focus is on what the participants said, not on the number of participants who expressed an idea. In focus group research, the unit of analysis is the group itself and not the individual participants. As a result, discussions of focus group proceedings use words like "most" or "only a few" to indicate how strongly an idea was voiced by the group.

All focus group sessions conducted for this project were recorded. Supporting comments illustrate the observed themes in the participants' own words. No attempt was made to quantify the number of comments made on any theme, which is consistent with the qualitative nature of this analysis.

Limitations of the Focus Groups

As with any research methodology, the use of focus groups for gathering data has limitations that were carefully considered when designing and implementing the focus group sessions. To the degree possible, steps were taken to minimize the effect of these limitations. These limitations include the following:

- While the social environment in focus groups is a significant strength because this environment allows participants to influence and share with one another, they sometimes result in detours or diversions in the discussion, requiring the moderator to use effective facilitation skills to keep the discussion focused.
- To save time, respondents were asked to nod when they agreed and speak when they had a different perspective or opinion.
- Participant responses during focus groups must be interpreted within the context of group interaction. Care is needed to avoid lifting comments out of context or coming to premature conclusions.
- Given the small number of participants in the focus groups, they are not meant to be representative of the population.
- Because of the relatively small number of participants in each group (generally 10 or fewer), groups can vary considerably, with each group tending to assume distinct characteristics.

For details about the structure of the focus groups, see "Appendix E: Residential Focus Group Moderator Guide," "Appendix F: Commercial Focus Group Moderator Guide," and "Appendix G: ZEV Focus Group Moderator Guide."

Vehicle Ownership and Driving Patterns

Vehicle ownership varied by region and income levels among residential participants and by industry among commercial participants. Among residential participants, outside San Francisco, nearly all participants' travel relied entirely on their vehicles, but commercial participants in San Francisco and Los Angeles reported using third-party delivery and courier services.

Patterns in Residential Vehicle Ownership

All focus group participants had at least one vehicle in their households. **Table 2** shows the average number of vehicles in each residential group and the average household size. Participants in San Francisco tended to come from smaller households than participants from other regions — five participants live alone — and have fewer vehicles — six participants have only one vehicle. The focus group in Los Angeles had more participants with electric vehicles than any of the other focus groups; five of these participants owned electric vehicles, and a sixth had one previously.

Table 2: Household Size and Vehicle Ownership by Household Focus Group

Focus Group Location	# of Participants	Average HH Size	Average # of Vehicles in HH
San Francisco	8	1.63	1.38
Sacramento	9	2.78	2.56
Fresno	7	3.29	2.43
Los Angeles	9	2.78	2.44

Source: 2024 California Vehicle Survey, California Energy Commission

Patterns in Commercial Vehicle Ownership

The commercial focus groups included a wide variety of fleet owners, from small businesses with one employee and one vehicle, to fleets with more than 100 vehicles across the entire state. **Table 3** summarizes the commercial focus group participants. Vehicle ownership varied by industry. Fleets that moved large equipment or several people at a time tended to have larger vehicles. Fleets that were used only to get drivers from one place to another tended to have smaller vehicles and were more likely to have HEVs or BEVs. Some industries necessitated the use of vehicles that can be modified to add storage or tiedowns such as cargo vans. Other industries use their vehicles in rugged terrain or to tow heavy loads, so they require large diesel vehicles. All types of fleets were represented across the regions.

Table 3: Summary of Fleets and Firms in Commercial Focus Groups

Focus group Location	Average Fleet Size	Average Number of Employees	Number of Participants in Focus Group
Sacramento	5.7	47.2	8
Fresno	5.4	134.6	8
San Francisco	8	468.2	7
Los Angeles	35.9	1363.6	8

Source: 2024 California Vehicle Survey, California Energy Commission

Residential Driving and Other Travel Patterns

Typical driving patterns varied across regions. Broadly, participants in San Francisco reported driving less than the other three regions. Participants in Los Angeles reported spending the most time in their cars, and participants in Fresno reported driving the farthest regularly.

Most respondents said they used ride share or taxi services for travel to and from the airport, but rarely at other times. The only place where participants reported consistently using public transit was in San Francisco. In Sacramento and Los Angeles, participants reported being worried about their safety on public transit. In San Francisco, one participant expressed an interest in more active modes of transportation, but no other group included any participants planning to walk or bike more.

Participants across regions generally spent time in their vehicles commuting to and from work. Many participants reported that they used rental cars for long-distance trips outside their region. For instance, one participant in San Francisco who does not own a ZEV said she uses a rental car to drive to Tahoe or Los Angeles for trips.

Commercial Driving and Other Travel Patterns

Driving patterns among commercial participants varied widely by industry and fleet size. Some examples of vehicle usage among commercial participants across the four regions are summarized below:

- An aviation supply chain company in San Francisco with 14 light-duty vans and trucks that mainly services airports and has vehicles operating essentially 24/7.
- A specialist physician in San Francisco with one hybrid vehicle bought used with 150,000 miles who drives lab samples around the Bay area and is hoping to get another 200,000 miles out of the car.
- A cannabis business in San Francisco with a fleet of modified diesel-powered vans to carry product and money to stores and banks.
- An entertainment business in Sacramento with three vans that are used to transport performers and equipment across the western United States for shows.
- A certified public accountant in Sacramento who travels around Northern California meeting in clients' homes.
- A commercial and residential cleaning company in Sacramento with a van and a sedan that hauls cleaning equipment and workers around the Sacramento area.
- A healthcare services company for disabled adults in Fresno with 30 vans that transport patients across the Central Valley every day.
- A small catering business in Fresno with one van that is used to transport equipment to events across the Central Valley.
- An engineering consulting firm with one vehicle in Bakersfield and two vehicles in Fresno that each drive about 30 miles each day.
- A high-end entertainment business in Los Angeles that has two Aston Martins that are used to transport clients around the region.
- A cosmetics manufacturer in Los Angeles with four vans and a fleet of EVs used by the sales staff across California.

- A chain of gyms based in Los Angeles that has cargo vans for all their technicians, 70 of whom are in California and each of them drive about 20 miles per day.

Future Purchase Decisions and Desired Attributes

There was remarkable consistency across the regions about desired vehicle attributes among residential and commercial participants.

Desired Attributes Among Residential Participants

One of the most important vehicle attributes for residential participants across all regions was safety. One participant in Sacramento said of back-up cameras, "I think they make you so much more aware. I mean, the Navy uses like a five-billion-dollar ship, and they use cameras. I think it's great for our cars."

Another attribute that was important across regions was amenities such as the screen on the dashboard, sound system, seat warmers, interoperability with cell phones, and general comfort of the driving experience.

Only one residential participant, who was in San Francisco, explicitly mentioned "environmentally friendly" as a desirable attribute, but one participant in Fresno and one in Los Angeles also mentioned that they expect their next vehicle to be a hybrid electric vehicle.

The San Francisco and Los Angeles residential groups had participants who mentioned the importance of warranties and other dealer benefits when they purchase a vehicle, but the other regional groups did not discuss warranties.

The San Francisco residential and Los Angeles ZEV groups discussed range as a desirable attribute. In San Francisco, the group said that their vehicle must be able to go 250 miles without refueling or recharging, and in the ZEV group, participants said their vehicle must be able to go 300 miles.

A few other region-specific features that participants brought up are summarized below:

- The San Francisco group was distinct in mentioning anti-theft features in this discussion.
- The Sacramento group was distinct in mentioning horsepower or speed or both in this discussion.
- The Fresno group was distinct in mentioning backseat space in this discussion.
- The Los Angeles group was distinct in mentioning a spare tire in this discussion.

Desired Attributes Among Commercial Participants

While the residential groups had a fair amount of variation by region in the desired attributes, the commercial groups saw more variation in desired attributes by the industry that the participants' companies work in.

The commercial groups tended to bring up the desirability of autonomous features such as parking assistance, braking assistance, and lane centering more than the residential groups. While the residential groups talked about how these features make driving less fun, the commercial groups tended to emphasize how these features keep their drivers and their company's equipment safe.

Commercial groups across all regions also emphasized the desirability of durability, cargo space, and towing capacity. In the Sacramento group, one participant said, "The number one thing would be load and tow capacity," and another participant added, "Ability to transport … large amounts of awkward items…but people, too."

Commercial groups across all regions also emphasized reliability, which they discussed in terms of brand reputation. In the Fresno group, two participants specifically said they consider brand reputation as they think about their next vehicle purchase. When asked how they know if a vehicle will be reliable before they buy it, one participant who primarily used large trucks in their business said, "I go with reputation [and] experience, and you can ask around with all your guys in the trades. … They'll tell you what dies." Another participant who manages a fleet of HEVs that are driven by travelling salespeople said, "The [brand] more than anything … Toyotas can run forever. Those are the ones that hit a million miles."

Alternative Fuel Knowledge and Perceptions

Compared to previous iterations of focus groups conducted as part of the 2016 CVS, there was more widespread awareness of all nongasoline fuel types, but some misconceptions persist. There are also consistent concerns about ZEVs among both residential and commercial participants. Participants were provided with information about alternative fuels, and these handouts are in "Appendix H: Handouts for Focus Group Participants."

Residential Awareness

Participants in the residential and commercial groups were asked about their awareness of HEVs, PHEVs, BEVs, and FCEVs. In each group, nearly every participant was aware of HEVs, PHEVs, and BEVs, and each group had at least two participants who were aware of FCEVs.

However, there was consistent confusion about the difference between HEVs, PHEVs, and, to a lesser extent, BEVs. Residential participants were always asked about HEVs, then PHEVs, then BEVs, in that order. In the Fresno group, when participants were asked about their familiarity with HEV, the conversation immediately transitioned to BEVs, with one participant asking about HEVs, "Are they electric?" In San Francisco, Sacramento, and Fresno, residential participants were not certain about the difference between HEVs and PHEVs. In Sacramento, one participant asked if PHEVs used gas as a fuel, and after a bit of discussion about PHEVs, one participant in San Francisco specifically asked for a clarification about the difference between HEVs and PHEVs because they assumed that all hybrid vehicles had to be plugged in. This participant asked, "Is there a non-plug-in hybrid?"

The Los Angeles residential group was much more familiar with the differences across these fuel types; most participants in this group had heard of all the fuel types, most had driven a HEV and a BEV, and one participant had driven a FCEV. The LA group did not have any confusion about the difference between HEVs and PHEVs.

Most respondents reported being aware of where they could purchase diesel and where they could charge an electric vehicle. Across all regions, only the FCEV owner in the Los Angeles ZEV group knew where they could purchase hydrogen fuel, though one respondent in Fresno said they would have to go to either Harris Ranch or the Bay Area to purchase hydrogen fuel, and one participant in Sacramento reported knowing that the hydrogen fuel station always has a long line.

Commercial Awareness

Broadly, participants in the commercial groups tended to be more familiar with most of the alternative fuel types than participants in the residential groups. In particular, while participants in the residential groups had a hard time recognizing the difference between HEVs and PHEVs, nearly all participants in the commercial groups understood this difference, and many could point out models of vehicles with each fuel type. The one exception was the commercial group in Fresno, in which only two participants reported being familiar with PHEV and there was confusion about whether these were the same as either HEV or BEV.

Commercial participants were largely less familiar with FCEV than the other fuel types. Across all regions, about half of the commercial participants were familiar with FCEV. In Sacramento, only one participant in the commercial group knew where hydrogen fuel could be purchased. In Fresno, one commercial participant pointed out that fueling a FCEV was potentially simpler and certainly less time-consuming than charging a BEV, but they were unaware of any hydrogen fueling station in the Central Valley. Commercial participants in Los Angeles suggested that FCEVs are more environmentally friendly than BEV, but they agreed that they did not know where they could purchase hydrogen fuel other than at dealerships that sell FCEVs.

Most commercial participants were familiar with where they could purchase diesel fuel and charge electric vehicles. A couple of participants reported that they knew which brands of gas stations had hydrogen fuel available, but they did not specifically know which locations had the fuel.

Residential Consideration

Residential focus group participants tended to like lower fuel cost of HEVs, PHEVs, and BEVs compared to conventional gasoline vehicles. One participant in Los Angeles put it this way when comparing the costs of gasoline and the costs of electricity: "It is no comparison."

Participants across regions also believed that these vehicles need fewer repairs. However, the cost of the repairs remained a concern for several participants. One participant in Los Angeles said, "All repairs, maintenance, insurance are way higher on EVs than gas cars."

In the Los Angeles group, perhaps the most important feature of HEVs, PHEVs, and BEVs that participants mentioned was access to the HOV lane. One participant expressed it this way: "That sticker is golden. … You're going to want that sticker." A few participants mentioned buying a BEV solely for HOV lane access.

There was disagreement about the driving experience of HEV, PHEV, and BEV. One participant in Sacramento who owns a HEV said that their HEV handles well and "turns like butter." Another participant in that group who was particularly interested in cars that are powerful and fast cited the speed of Tesla as a selling point but was unsure about these features on other EVs. However, in the same group, another participant said of driving a HEV, "It felt like an appliance," suggesting that it did not have the same powerful feel as a conventional gasoline vehicle.

While participants tended to agree that HEVs, PHEVs, and BEVs needed fewer repairs, many participants were concerned that when they needed repairs, they would require specific mechanics who are difficult to find, take a long time, and be expensive. The significant cost of replacing the battery in a BEV or PHEV was raised by one participant in the Los Angeles group and one participant in the Sacramento group.

A few participants in each region's residential group pointed out that alternative fuel vehicles tend to look ugly or at least look obviously like alternative fuel vehicles. In Los Angeles, one participant said, "The designs … are a little out there. … The execution of it results in a kind of ugly car."

The most significant concerns that participants in the residential groups had about alternative fuel vehicles had to do with range and charging (and fueling in the case of FCEVs). In Fresno, one participant expressed this worry in terms of a trip from the Central Valley to Los Angeles: "I want to make it all the way to Los Angeles without having to stop and charge halfway there, and then wait an hour, two hours to charge the battery." This was the most consistent finding across all residential groups about alternative fuel vehicles.

In the Los Angeles group, one participant specifically mentioned the repair costs associated with alternative fuel vehicles. This participant said that in Los Angeles, it is not a question of if a driver will be in an accident, but when. Knowing this, the participant is hesitant to purchase an alternative fuel vehicle because they expect that it will be much more costly to repair.

Commercial Consideration

Many of the same considerations raised in the residential groups also came up in the commercial groups. Like residential participants, commercial fleet owners worried that PHEVs and BEVs would not be able to meet their needs in terms of travel range per charge. Participants in the commercial groups regularly mentioned that, despite recognizing a difference in the price of fuel for PHEVs and BEVs, if these vehicles need to be charged during the day for longer than it takes to fill a gas tank at a gas station, they will not be viable options for their fleets. The primary concern for commercial operators is getting their drivers where they need to be when they need to be there, and there was considerable concern that vehicles that need to be plugged in will hinder that ability.

Commercial fleet owners with vehicles that need to haul equipment or passengers or both also cited the lack of model availability as reasons they are not considering HEVs, PHEVs, BEVs, and FCEVs in their fleets.

Among some fleet owners with several diesel vehicles in their fleets, there was a sense that FCEVs might offer a better long-term replacement for their diesel vehicles than BEVs or HEVs. However, they noted that given the lack of fueling infrastructure, model availability, and increasing availability of BEVs, they were not optimistic that FCEVs would be an option for their fleets.

Smaller fleet owners with predictable driving needs tend to have more favorable attitudes about PHEVs and BEVs. Across all regions, three small fleet owners either had planned or were planning to purchase HEV, PHEV, or BEV. These fleet owners saw the benefits of these vehicles coming from fuel cost savings, tax incentives, and lower maintenance costs compared to conventional vehicles. However, small fleet owners with specific vehicle needs, such as towing capacity, storage space, or luxury vehicles, all tended to cite model availability as the main deterrent for electric vehicles.

ZEV Owner Attitudes and Perceptions

The ZEV focus group in Los Angeles included residential and commercial vehicle owners. The data from this group offer an insight into the experience of ZEV drivers that differ from participants in the other groups, many of whom had not owned or driven a ZEV before.

The ZEV group included 10 participants. Five participants owned or leased more than one ZEV, and four owned or leased at least one conventional gasoline vehicle in addition to their ZEV. One participant had an FCEV, one participant had a PHEV, and nine had BEVs. Three participants had solar panels at home, and none had a backup battery for their home. Six of the participants primarily charge their vehicles at home, and four primarily use public chargers.

The most commonly reported reason participants purchased their ZEV was to gain access to HOV lanes, which is a major benefit in the Los Angeles area.

In addition to accessing the HOV lane, some participants noted that they like their ZEV for the following reasons:

- They are environmentally friendly.
- They are the future of transportation technology.
- They are cheaper to operate than conventional gasoline vehicles.
- With a charger at home, they are more convenient to refuel than conventional gasoline vehicles.

ZEV Owner Charging Behavior and Concerns

Four of the participants in the ZEV group said that they would consider purchasing a conventional gasoline vehicle for their next vehicle. They cited poor charging infrastructure and long charging times as motivation for not getting another ZEV.

Poor charging infrastructure was the most cited complaint about ZEV ownership. Four participants who own BEVs did not have Level 2 charging capabilities at home, so they relied nearly entirely on public charging facilities. The FCEV owner in the group reported that there was a station relatively close to their home, but it is regularly out of fuel, and they must drive 30 minutes to the next nearest station. This participant described both refueling their FCEV and BEV as a "nightmare." Others pointed out that using a public charger always entails dealing with broken chargers and long lines. One participant who said that they do not use their BEV for long trips still said that "it's a terrible infrastructure. There's [*sic*] two locations [near me] … in a mall and it's terrible. Somebody's in line, … or they're broken."

Even participants who have Level 2 chargers at their homes reported frustration with public charging infrastructure. Range anxiety kept several participants from using their ZEVs for trips outside the region, and multiple participants shared specific incidents in which they traveled a long distance only to find broken or busy chargers that significantly delayed their travel. Most participants agreed that, as burdensome as public charging is in the Los Angeles region, outside the region, charging was even more unpredictable.

Some participants reported more difficulty with home charging than others. One participant who has exclusively owned BEVs for the last decade reported a completely frictionless experience with two Level 2 charging units at home. However, another participant reported that while they are charging their vehicle, they cannot use any other electrical devices in the house because it will trip a circuit breaker.

Autonomous Features and Perceptions of Full Autonomy

The discussion in the focus groups about vehicle autonomy was divided into two sections. First, participants were asked about their attitudes regarding autonomous features such as adaptive cruise control and automatic braking. The second section focused on fully autonomous, or self-driving vehicles. Broadly, residential participants were much less positive about autonomous features than commercial participants, but there was agreement in nearly every group that fully autonomous vehicles pose significant safety challenges that are difficult for many people to overcome. Information about autonomous features was provided to participants, and this information is in "Appendix H: Handouts for Focus Group Participants."

Residential Attitudes About Autonomous Features

Across the residential groups, many participants saw autonomous features as disruptive to the driving experience. Outside Los Angeles, most of the residential groups settled on the idea that features that warn the driver of dangers were preferable to features that take control of the vehicle such as automatic braking or lane change assistance. In each of these groups, at least one participant shared a story about an autonomous feature making a mistake, such as automatic braking engaging when it should not or lane centering not dealing with merging lanes well.

The groups that had the most positive attitudes about autonomous features were the Los Angeles residential and ZEV groups. One participant in the Los Angeles residential group said about autonomous features, "Anything that keeps me safer is better." One participant in the ZEV group specifically mentioned that they have been saved from accidents by the automatic emergency braking feature.

Commercial Attitudes About Autonomous Features

Commercial fleet owners tended to place a high value on autonomous features for their fleets. Most fleet owners in the commercial groups saw these features as improving the safety of their vehicles and their drivers. Some fleet owners pointed out that they, like the residential participants, did not like autonomous features on their own vehicles, but they did place a high value on them for their fleets.

However, there were exceptions to commercial participants' favorable attitudes toward autonomous features. Owners of small fleets who were also drivers were notable exceptions. One small-fleet owner in Sacramento emphasized that they do not trust autonomous features.

The Fresno group was the most vocally opposed to the autonomous features in their fleets' vehicles. One participant felt that these features take away from driving experience and create a false sense of security for their drivers who are more capable of driving safely than any of these autonomous features.

Attitudes and Perceptions About Fully Autonomous Vehicles

Residential and commercial participants were united in their distrust about the safety of fully autonomous vehicles. Participants were asked how fully autonomous vehicles might affect theirs or the fleets' driving behavior or vehicle needs. Although the moderator asked participants to assume that the technology was safe when they answered this question, safety remained the primary topic of conversation. Outside the Los Angeles groups, there was near unanimity that fully autonomous vehicles will not be safe on the road unless all vehicles are fully autonomous.

Participants were asked to think about how the availability of fully autonomous vehicles might impact their travel behavior and vehicle needs. One participant in San Francisco said that if fully autonomous vehicles were available, they would only be interested in them as a rideshare service, but that this service might mean they would no longer need a personal vehicle. However, most participants outside Los Angeles could not express if or how fully autonomous vehicles would change their travel behavior; they tended to believe that the availability would not affect their vehicle ownership. Commercial owners said that they would still need employees in the vehicle to make the delivery or work at the job site, so fully autonomous vehicles would not benefit them or change their vehicle needs.

In the Los Angeles residential and ZEV groups, participants were more open to the idea of fully autonomous vehicles operating safely in the future and believed the availability of fully autonomous vehicles would change their households' vehicle needs and travel behavior. One participant in the Los Angeles residential group said they would love it if a car could drive their elderly parents around town or find a parking spot after dropping off the driver. Several others said that they would use fully autonomous vehicles for rideshare so frequently that they would not need a second vehicle in their home.

However, participants did point out that there are still several safety concerns that need to be addressed before the widespread adoption of fully autonomous vehicles is a reality. Some of these concerns included continued testing on the roads to ensure that vehicles are safe in all conditions and security of the driving software to prevent malicious cyberattacks on vehicles.

One participant in the Los Angeles ZEV group participated in the Waymo pilot program in which they had on-demand access to a Waymo self-driving vehicle for two weeks. This participant was glowing in evaluation of the technology. They felt entirely safe working in the back seat while the vehicle drove them to work. They would be enthusiastic about using a self-driving vehicle to take their children to school or sports, and they would feel completely safe having their children ride in the vehicle alone. This participant's experience seemed to help other members of the group have a more favorable outlook on fully autonomous vehicles in the future. However, two participants said they do not trust the autopilot feature on their Tesla vehicles, and one participant said that they love to drive, so it would not be easy to transition to a fully autonomous vehicle.

Attitudes and Perceptions About Vehicle-to-Grid Connectivity

Participants in all focus groups were asked about their understanding of and attitudes toward vehicle-to-grid (V2G) connectivity. Participants in the residential and commercial focus groups were asked if the ability to use an electric vehicle to power their home or business location would make them more likely to purchase an electric vehicle. These participants were also asked if the ability to be paid to discharge an electric vehicle battery into the public electric grid would make them more likely to purchase an electric vehicle.

Participants in both the residential and commercial groups were initially confused about the idea of being paid to discharge their vehicles' electricity into the grid. They suggested that it didn't make much sense to pay for the electricity to charge their vehicle and then be paid for discharge, and they were concerned that this would ultimately lead to paying for electricity that they don't in effect use. However, in each group, at least one participant suggested that they could charge their vehicle during off-peak usage times and then discharge their vehicle during on-peak usage times and thus make money by discharging. Despite this clarification, most participants thought that this connectivity would not be beneficial to them and were concerned that an electric company would be able to discharge their vehicle battery without their consent or knowledge.

Participants in the commercial groups emphasized that, if they had electric vehicles in their fleet, they needed these vehicles to be fully charged and ready to drive, so discharging the batteries, even if they could make a little money by selling the electricity, would not benefit their businesses. No one suggested that V2G connectivity would make them more likely to purchase an electric vehicle.

Participants in the ZEV owner group were not asked about whether V2G connectivity would make them more likely to purchase a ZEV, since they are already ZEV owners. These participants were asked generally about their willingness to participate in a vehicle-to-grid program. Like the other groups, participants in the ZEV group were initially unsure about how V2G connectivity could benefit them, but when the idea of charging during the off-peak and discharging during the peak was introduced, they were broadly supportive and interested in seeing if they could save money with this program.

Discrete Choice Experiment Review

Overall, across all regions, participants reported that the discrete choice experiments were easy to understand, and all participants were able to read the directions and attribute descriptions and then select their preferred vehicle. In the AV discrete choice experiments, all participants successfully read the autonomy level descriptions and selected their preferred level for a given vehicle.

Most of the criticisms of the experiments stemmed from the alternatives not being tailored to the individual, which is an artifact of the printed experiments presented in the focus groups. The online survey will customize the experiments to the preferences of each respondent. Furthermore, the AV discrete choice experiments will be based on an actual vehicle selected in the vehicle class experiment. In the focus groups test, participants were just told to assume they chose a given vehicle and consider which level of autonomy they would prefer at the given prices.

The one piece of the experiment that was targeted for specific feedback was the fuel station availability attribute for BEVs. The moderator asked participants how they might think about public charging station availability. For instance, do they think about what percentage of public parking lots have chargers, how many miles away a public charging station is, how many minutes away a public charging station is, or something else. Most said they thought of station availability in terms of minutes to a charger, but that they also had to consider the wait time to use that charger since most of the time chargers are being used. This was valuable feedback, and the attribute was revised in the stated preference experimental design to include time to charge and wait time. "Appendix I: Example Discrete Choice Experiments" lists the example discrete choice experiments that were provided to focus group participants.

Summary and Recommendations for Survey Modifications

Several consistent themes emerged across the nine focus groups conducted as part of the 2024 CVS. Some of the key themes and recommended changes are highlighted below.

Participants were not generally concerned about fuel economy, operating costs, or fuel types when stating their "must have" and "nice to have" vehicle features. The most important features noted were related to safety, comfort, and technology.

Both residential and commercial participants had some trouble differentiating between hybrid, plug-in hybrid, and battery-electric power trains. Most understood the difference between gasoline and BEVs, but hybrid and plug-in hybrid vehicles were sources of confusion. Participants were able to better understand the differences after being presented with definitions of each fuel type, and most indicated that the definitions were straightforward and easy to understand. The survey team modified the survey pretest language to minimize confusion between hybrids and PHEVs.

Concerns voiced about BEVs were almost universally related to vehicle range, the availability of charging infrastructure, and the time spent recharging or waiting for a public charger to become available. The concern that ZEV owners spent the most time discussing was the availability of chargers, both due to long lines and chargers out of order. The concern that non-ZEV owners in the residential groups spend the most time discussing was range; they tended to worry about driving as far as they needed without requiring a lengthy stop to recharge. Non-ZEV owners in the commercial group emphasized both range — similar to the residential group — and the lack of ZEV model types that meet their business needs. As a result, improving public charging infrastructure and increasing awareness of that infrastructure will be important to increasing electric vehicle adoption in the state.

When thinking about refueling times for plug-in vehicles, participants noted that the time to get to a charger and the time spent waiting for a charger to become available were important considerations. This attribute was modified in the vehicle choice discrete choice experiment to include both of these times.

Participants were generally unfamiliar with fuel cell vehicles, and most are not likely to consider purchasing these vehicles in the near future. This fuel type will likely have low consideration in the vehicle choice discrete choice experiments.

Only a handful of participants mentioned compressed natural gas vehicles as a fuel type, and none indicated that this was a desirable fuel type. This supports the decision to remove this fuel type from the vehicle type choice discrete choice experiments.

Opinions of autonomous vehicle features vary widely across participants but are generally viewed more favorably by commercial fleet managers compared to residential drivers. Both residential and commercial fleet participants are widely skeptical of fully autonomous vehicles and would need to see demonstrated operation safely over a period before feeling comfortable riding in a fully autonomous vehicle.

In general, participants expressed little concern about the vehicle type choice and AV discrete choice experiments, and only minor modifications were recommended to improve the access to charging attribute for plug-in vehicles. These recommendations were incorporated into the pretest survey questionnaire and discrete choice experimental design.

The survey team modified the survey pretest questionnaires language and metrics to incorporate the focus group sessions feedback.

CHAPTER 5: Survey Pretests and Final Instruments

Survey pretests were conducted before implementing the full survey data collection effort. The pretests of surveys were an important step in the overall study because the 2024 CVS questionnaires and recruitment processes differed in several important ways from past CVS projects. The survey pretests helped the project team evaluate three primary aspects of the study:

1. Changes in the questionnaire content and design from previous surveys
2. The recruitment survey process and resulting participation rates
3. The ability of SP data to support the estimation of vehicle choice models

The pretest was conducted from May to mid-June 2024. During the pretest period, the survey team obtained 289 residential responses and 375 commercial responses. This report summarizes the approach and outcomes of the pretest for the residential and commercial surveys, including the separate sampling frames used to supplement the ZEV owner survey.

Following the pretest, the survey team reviewed the recruitment statistics and the data that were collected to identify potential opportunities to improve the survey approach. The recommendations for changes to the survey approach, recruitment methods, and questionnaires are provided at the conclusion of this chapter.

The project team also estimated discrete choice models for the residential and commercial vehicle choice data, as well as the autonomous vehicle choice data, to ensure that the design and data could support the estimation of the vehicle choice models. While the signs and magnitude of the coefficient estimates were reasonable and intuitively correct, many of the estimates were not statistically significant due to the comparatively small samples sizes collected during the pretest.

Residential Pretest

The residential survey pretest was administered to California residents using two sampling frames:

1. A general address-based sampling (ABS) frame of households in California
2. An online market research panel sampling frame of individuals in California

The targeted sample size for the residential pretest survey was 200 complete surveys, with 150 completes to be obtained from the address-based sampling frame and the remaining 50 completes to be obtained from the research panel sampling frame.

The survey team developed a separate sampling frame to target individuals with a ZEV registered in California. This approach was used to ensure the sample of ZEV owners was large enough to evaluate independently in the survey analysis. This section documents the results of the survey administration to the general residential address-based sampling frame and the online market research panel sampling frame. The results of the residential ZEV sampling frame are documented under the heading Residential ZEV Pretest of this chapter.

Residential Pretest — Address-Based Sampling

The project team worked with Marketing Systems Group (MSG) to select a random sample of household addresses within California. MSG maintains an address-based sampling frame based on the USPS Computerized Delivery Sequence File (CDS), which MSG licenses. The ABS sampling frame contains more than 158 million residential addresses, covering nearly 100 percent of all households in the United States. For this survey, the 58 counties in California were grouped into six geographic regions, and responses were monitored to ensure adequate representation from each of the six regions of interest (**Table 4**).

Table 4: Counties in Survey Regions

Survey Region	Counties
San Francisco	Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano, Sonoma, San Francisco
Los Angeles	Los Angeles, Orange, Imperial, Riverside, San Bernardino, Ventura
San Diego	San Diego
Sacramento	El Dorado, Placer, Sacramento, Sutter, Yolo, Yuba
Central Valley	Fresno, Kern, Kings, Tulare, Madera, San Joaquin, Stanislaus, Merced
Rest of State	Alpine, Amador, Butte, Calaveras, Colusa, Del Norte, Glenn, Humboldt, Inyo, Lake, Lassen, Mariposa, Mendocino, Modoc, Mono, Monterey, Nevada, Plumas, San Benito, San Luis Obispo, Santa Barbara, Santa Cruz, Shasta, Sierra, Siskiyou, Tehama, Trinity, Tuolumne

Source: 2024 California Vehicle Survey, California Energy Commission

The survey team estimated the response rate for the proposed address-based recruitment to be 4 percent on average, with some variation expected by region. This assumed response rate implied that 3,750 invitations would need to be distributed across the state to achieve the pretest sample size target of 150 complete surveys. **Table 5** presents the distribution of households across the six regions, along with the corresponding number of invitations distributed to households in each region.

Table 5: Residential Pretest — ABS Sampling Plan

Survey Region	Households Count	Households Percent	Invitations Count	Invitations Percent
San Francisco	2,767,439	21%	779	21%
Los Angeles	6,161,960	46%	1,735	46%
San Diego	1,149,157	9%	324	9%
Sacramento	928,298	7%	261	7%
Central Valley	1,319,872	10%	372	10%
Rest of State	989,096	7%	279	7%
Total	**13,315,822**	**100%**	**3,750**	**100%**

Source: 2022 American Community Survey 5-Year Estimates.

Residential Pretest — Research Panel Sampling

The project team worked with Dynata, a global online sampling and digital data collection company, to obtain the remaining 50 pretest survey responses. Qualifying panel members were recruited via email sent directly by Dynata. Panelists entered the survey through customized links that controlled survey access and recorded survey status. The responses from the research panel were targeted and monitored across the same six regions presented in **Table 4** above.

Residential Pretest — Summary of Recruitment and Data

The residential pretest collected complete surveys from 233 respondents, including 183 from the address-based sampling frame and 50 from the research panel sampling frame (**Table 6**). The number of complete surveys for both sampling frames exceeded the sample size targets for the pretest.

Table 6: Residential Pretest — Targeted Completes and Actual Completes by Sampling Frame

Sampling Frame	Targeted Pretest Surveys	Actual Pretest Surveys
Address-based	150	183
Research panel	50	50
Total	**200**	**233**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 7 presents the distribution of completed surveys by region for each sampling frame compared to the targeted proportion of completes. Los Angeles has the highest representation across all categories, accounting for 43 percent of responses. The research panel responses seem to overrepresent San Francisco (26 percent of panel responses vs. 21 percent of households) and underrepresent the "Rest of State" (2 percent of panel responses vs. 7 percent of households). Address-based responses appear to match the household distribution more closely for most regions. There are minor discrepancies between total responses and household percentages, particularly for San Francisco (23 percent of total responses vs. 21 percent of households) and Los Angeles (46 percent of total responses vs. 43 percent of households).

Table 7: Residential Pretest — Distribution of Complete Surveys by Survey Region

Survey Region	Address-Based Responses	Research Panel Responses	Total Responses	2022 ACS Households
San Francisco	22%	26%	23%	21%
Los Angeles	43%	42%	43%	46%
San Diego	11%	6%	10%	9%
Sacramento	7%	8%	7%	7%
Central Valley	9%	16%	10%	10%
Rest of State	8%	2%	7%	7%

Source: 2024 California Vehicle Survey and the 2022 American Community Survey 5-year estimates.

Table 8 presents the counts of postcards distributed, completes, dropouts, disqualifications, total logins, and response rate (number of completes/number of postcards distributed) by region for the address-based sampling frame. Dropouts are respondents who began but did not complete the survey, while disqualifications represent respondents who were disqualified from participating in the survey based on their responses to the qualification questions. Response rates varied by region, with the highest rate of completion in the San Diego region and the lowest rate in the Central Valley.

During the survey pretest, 231 respondents from the general residential sampling frame entered the online survey and 183 completed the questionnaire. This finding represents a completion rate of 4.9 percent, which was higher than the assumed 4 percent completion rate for the pretest.

Table 8: Residential Pretest — ABS Response Summary by Region

Region	Invitations	Completes	Dropouts	Disqualifications	Total Logins	Response Rate (Completes)
San Francisco	779	41	5	2	48	5.3%
Los Angeles	1,735	79	22	3	104	4.6%
San Diego	324	20	4	0	24	6.2%
Sacramento	261	12	3	0	15	4.6%
Central Valley	372	16	4	0	20	4.3%
Rest of State	279	15	4	1	20	5.4%
Total	**3,750**	**183**	**42**	**6**	**231**	**4.9%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 9 presents the counts of completes, dropouts, disqualifications, and logins by region for the residential panel sampling frame. During the survey test administration phase, 89 respondents from the panel sampling frame entered the residential survey; of these respondents, 50 completed the questionnaire.

Table 9: Residential Pretest — Research Panel Response Summary by Region

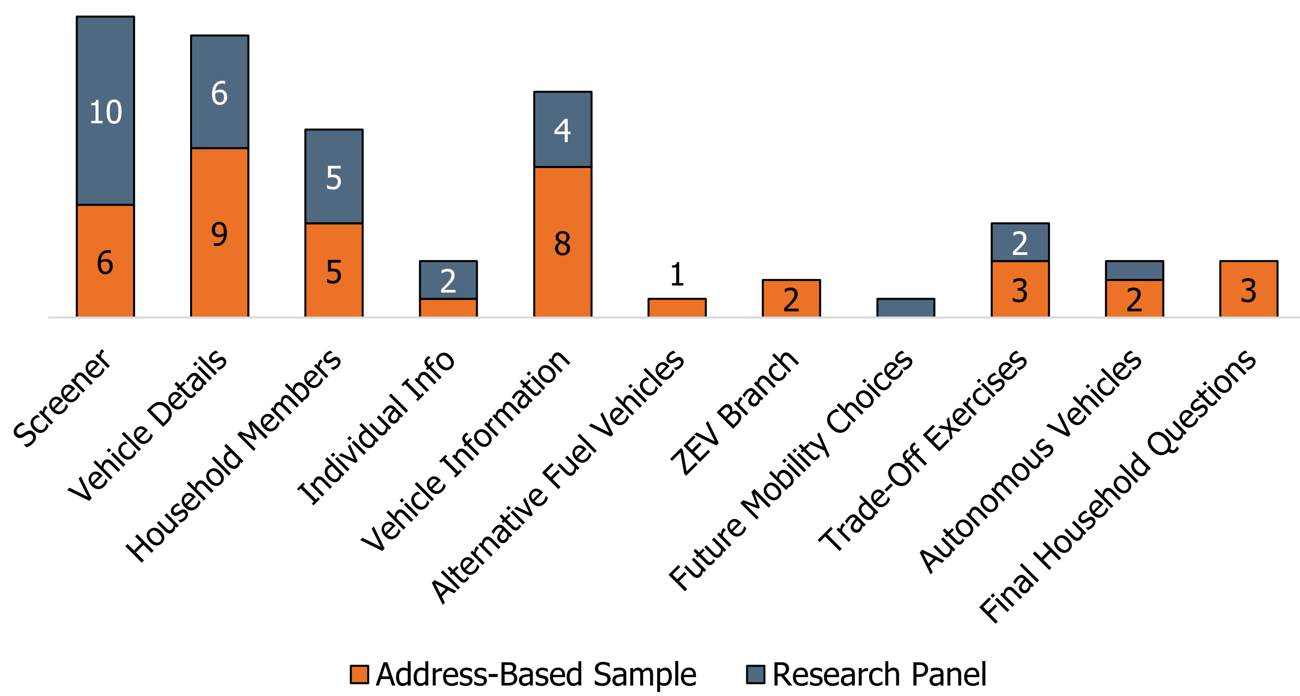
Region	Completes	Dropouts	Disqualifications	Total Logins
San Francisco	13	3	2	18
Los Angeles	21	8	2	31
San Diego	3	4	0	7
Sacramento	4	3	0	7
Central Valley	8	4	0	12
Rest of State	1	0	0	1
Unknown	0	9	4	13
Total	**50**	**31**	**8**	**89**

Source: 2024 California Vehicle Survey, California Energy Commission

Of the 10 respondents who were terminated from the survey, 6 indicated they do not participate in the household decision-making process when acquiring a new vehicle, 2 preferred to take the survey in Spanish, 1 did not meet the minimum age requirement, and 1 was not a California resident.

Of the respondents who partially completed the survey, 15 dropped out at the household vehicle details section. **Figure 1** shows the dropout locations for the survey pretest.

Figure 1: Residential Pretest — Dropout Locations



Source: 2024 California Vehicle Survey, California Energy Commission

Table 10 shows survey completion time statistics for the 239 respondents who finished the survey. The median completion times are relatively long but not unexpected considering the length and complexity of the questionnaire. The median completion time for research panel respondents was about 39 percent faster than respondents recruited through the address-based sampling frame. The maximum survey duration for respondents from the ABS — which is more than six days — is likely due to a respondent who began the survey and then left their web browser open and did not return to the survey for several days.

Table 10: Residential Pretest — Survey Completion Time Statistics

Survey Duration	ABS Duration (minutes)	Research Panel Duration (minutes)
Minimum	9	8
Maximum	8,769	144
Median	36	22

Source: 2024 California Vehicle Survey, California Energy Commission

Table 11 summarizes the number of vehicles owned at the household level for each sampling frame. Vehicle ownership at the household level from the survey approximately matches the distribution of household vehicle ownership in California.

Table 11: Residential Pretest — Number of Household Vehicles

Number of Vehicles	Address-Based Sampling Count	Address-Based Sampling Percent	Research Panel Count	Research Panel Percent	2022 ACS Estimate Percent
0 Vehicles	4	2%	1	2%	7%
1 Vehicle	62	34%	28	56%	30%
2 Vehicles	75	41%	14	28%	37%
3 Vehicles	27	15%	6	12%	16%
4 or more	15	8%	1	2%	10%
Total	183	100%	50	100%	100%

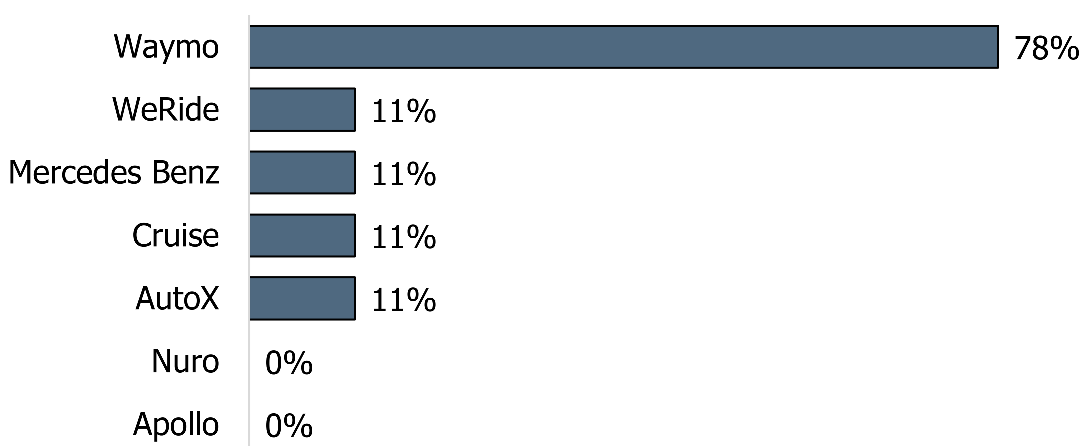
Source: 2022 American Community Survey 5-year estimates.

Residential Pretest — Review of Changes

This section examines the responses to questions added to the 2024 CVS that were changed between the pretest and the full implementation of the survey.

Of those respondents who were aware of autonomous ride-hailing services, only 5 percent had used a self-driving ride-hailing service. **Figure 2** shows which services these respondents reported using. The most common was Waymo, with all others selected only by one or zero respondents. Because of the lack of variation in response, and the low proportion of respondents who had used any self-driving ride-hailing service, RSG recommended removing this question to reduce respondent burden.

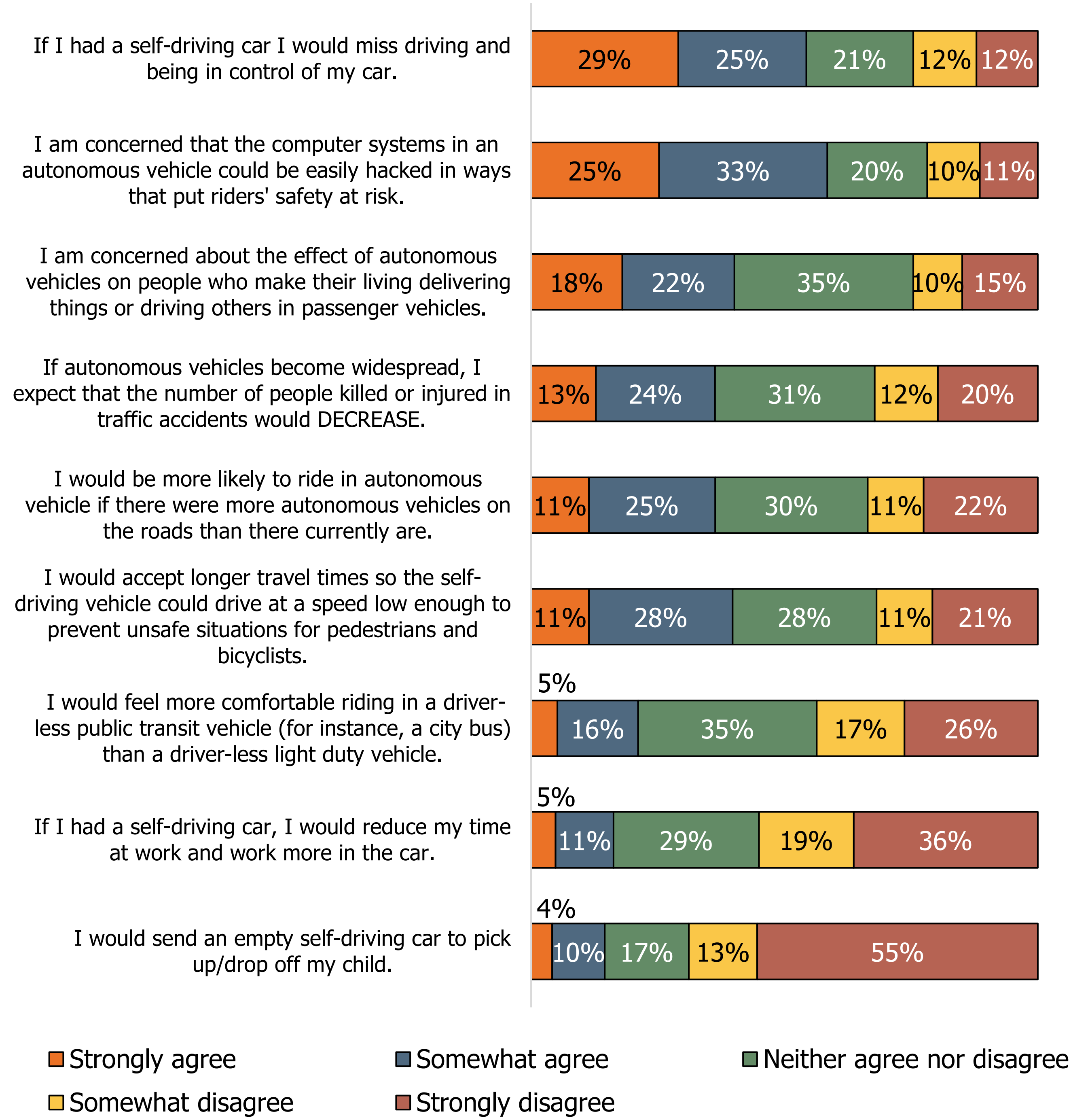
Figure 2: Residential Pretest-Autonomous Ride-Hail by Company (Select All That Apply)



Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were given a set of attitude statements related to autonomous vehicles and asked to rate whether they agreed or disagreed with them (**Figure 3)**. RSG recommended removing some of these statements due to their length. In the full implementation of the survey, the statement "I would feel more comfortable riding in a driver-less public transit vehicle (for instance, a city bus) than a driver-less light-duty vehicle" was removed.

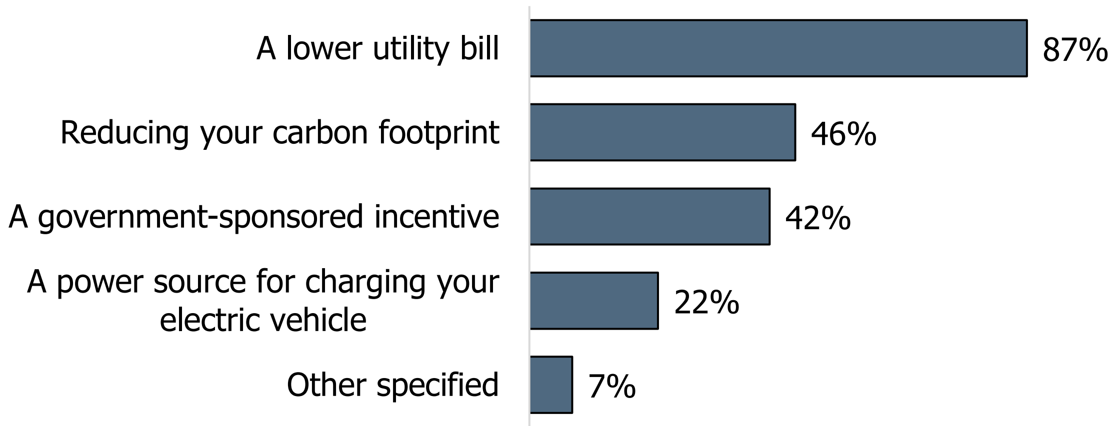
Figure 3: Residential Pretest-AV Attitude Statements



Source: 2024 California Vehicle Survey, California Energy Commission

When asked if they had solar panels installed on their residence, 23 percent of respondents did. When these respondents were asked what year they installed their solar panels, the median year was 2018. **Figure 4** shows respondents' motivations for installing solar panels. The most common was a lower utility bill, at 87 percent. Most respondents who selected "Other" specified that they purchased a home with solar panels already installed. RSG recommended including "They were installed before I moved in" as an option which clears other selections. Of the respondents without solar panels, 14 percent stated that they are planning to install them within the next five years.

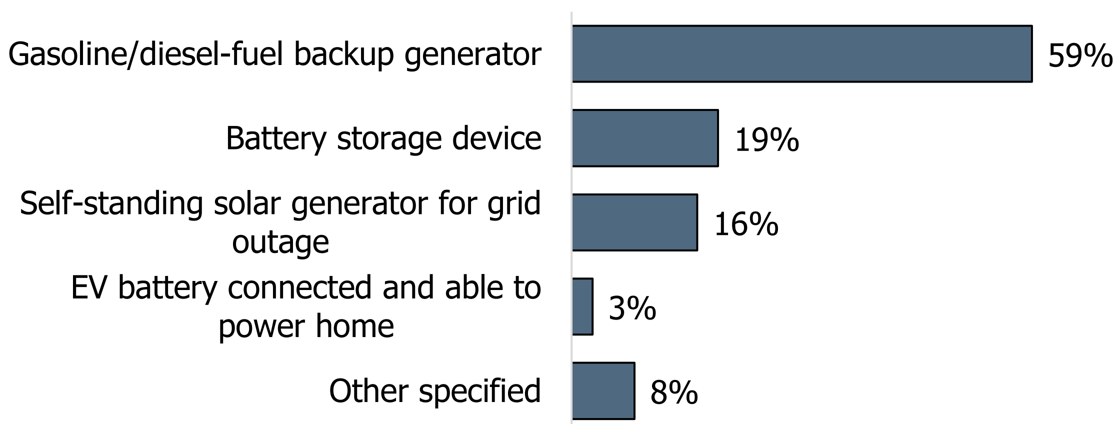
Figure 4: Residential Pretest-Motivation for Installing Solar Panels (Select All That Apply)



Source: 2024 California Vehicle Survey, California Energy Commission

When asked if they had a backup energy source in case of a grid outage, 13 percent of respondents stated they did. Respondents without backup power were asked if they plan to install a source within the next five years, and 23 percent did. **Figure 5** shows the type of backup energy source that respondents had. More than half (59 percent) had a gasoline or diesel fuel generator, while only one respondent was able to power their home with their EV. One respondent who selected "Other" specified they used a propane generator, so RSG recommended including natural gas and propane in the fuel generator option in the full implementation. Respondents with backup energy sources had a median of two such devices.

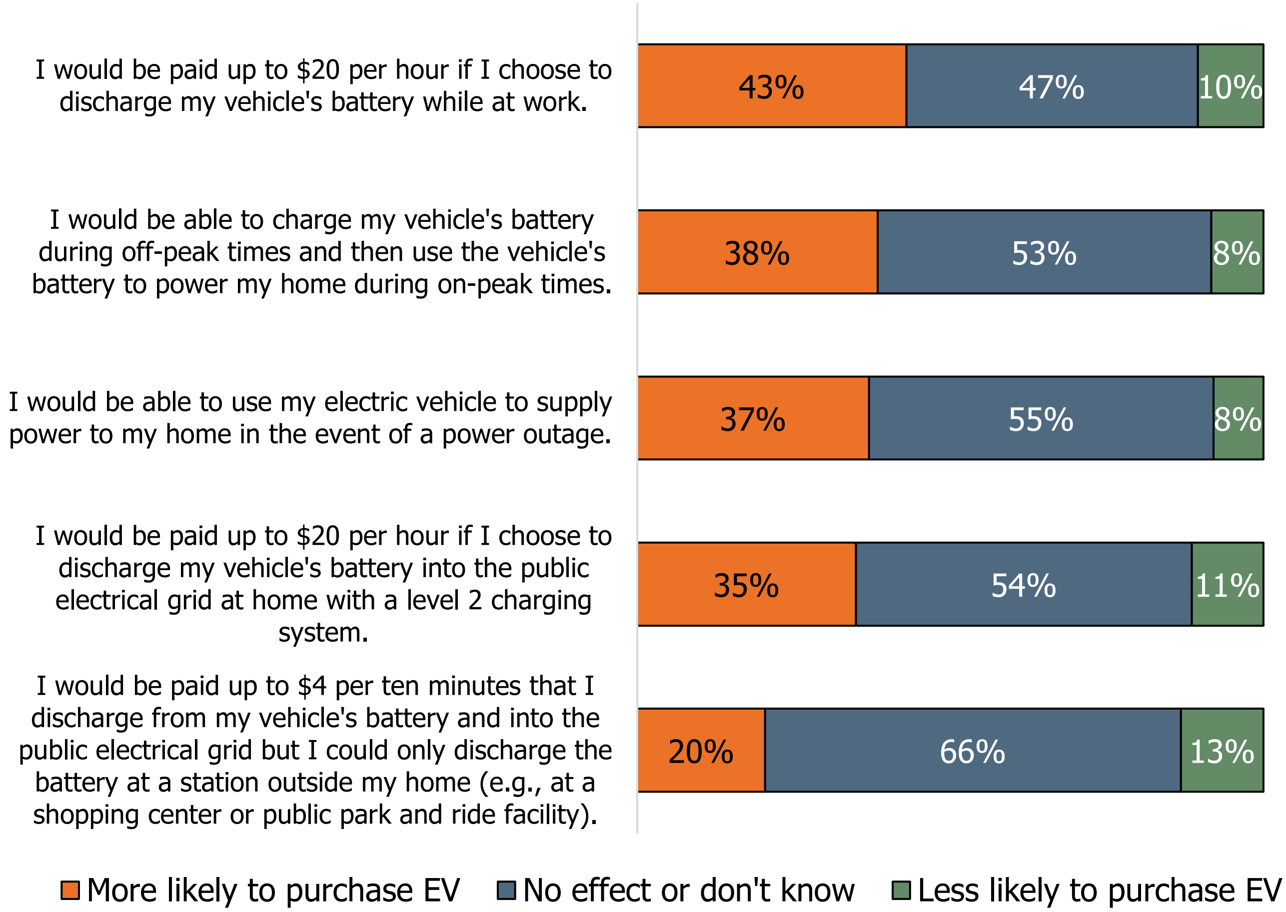
Figure 5: Residential Pretest-Backup Energy Source Type (Select All That Apply)



Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were then given scenarios and asked to consider whether they would be more or less likely to purchase an EV (**Figure 6**). As two-thirds (66 percent) of respondents said that only being able to discharge to the grid away from their home would have no effect on their likelihood of purchasing an EV or they did not know, RSG recommended removing this statement in the full launch of the survey.

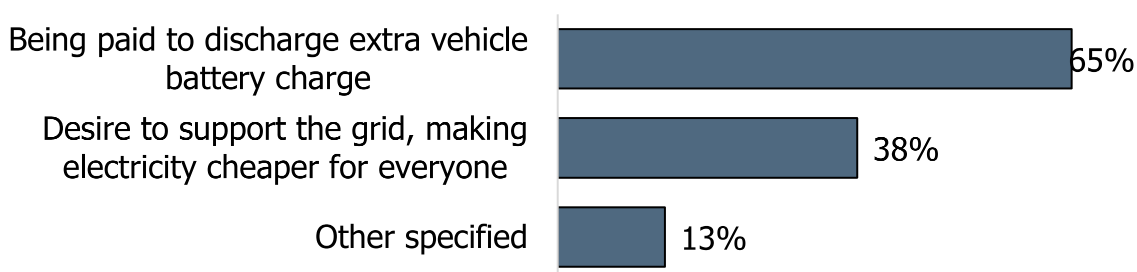
Figure 6: Residential Pretest Effect of Vehicle-to-Grid Technology on EV Consideration



Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were then given factors that may increase (**Figure 7**) their participation in vehicle-to-grid integration. Nearly two-thirds (65 percent) would be more likely to participate if they were paid, and more than half (55 percent) would be less likely to participate due to concerns about battery wear. Most respondents who selected "Other" on either question stated that they would not participate in any case. RSG recommended adding "I would not participate" as an option for this question in the full implementation of the survey.

Figure 7: Residential Pretest Factors That May Increase Participation in Vehicle-to-Grid Integration (Select All That Apply)



Source: 2024 California Vehicle Survey, California Energy Commission

Residential Pretest — Discrete Choice Experiment Results

While the sample size of the pretest was too small to finalize choice models, this section shares high-level statistics about which vehicles were chosen in each discrete choice experiment.

Table 12 shows how many times each vehicle was chosen in the vehicle choice discrete choice experiments by position. Vehicle 1 was based on the respondent's consideration set and was chosen 68 percent of the time. While it is not surprising the reference vehicle is chosen more frequently than alternatives, RSG recommended randomizing the location of the reference vehicle in the discrete choice experiments to avoid potential ordering effects.

Table 12: Residential Pretest — Vehicle Choice in SP

Choice	Count	Percent
Reference Vehicle	1,562	68%
Vehicle 2	342	15%
Vehicle 3	228	10%
Vehicle 4	180	8%
Total	**2,312**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 13 through **Table 16** show choices by vehicle class, fuel type, prestige level, and model year. However, because these variables depend on the vehicles in each respondent's consideration set, the attribute levels are not presented an even number of times across the sample.

Table 13 shows that vans and pickups were chosen in only 15 percent of experiments.

Table 13: Residential Pretest — Vehicle Choice in DCE by Vehicle Class

Vehicle Class	Count	Percent
Car-Subcompact	64	3%
Car-Compact	308	13%
Car-Midsize	499	22%
Car-Large	89	4%
Car-Sport	104	4%
Car Subtotal	*1,064*	*46%*
SUV-Subcompact	105	5%
SUV-Compact	193	8%
SUV-Midsize	497	21%
SUV-Large	111	5%
SUV Subtotal	*906*	*39%*
Van-Compact	67	3%
Van-Standard	51	2%
Van Subtotal	*118*	*5%*
Pickup-Compact	126	5%
Pickup-Standard	98	4%
Pickup Subtotal	*224*	*10%*
Total	**2,312**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 14 shows vehicle choice by fuel type. Gas HEVs were chosen nearly as often as gasoline-only vehicles.

Table 14: Residential Pretest — Vehicle Choice in DCE by Fuel Type

Fuel Type	Count	Percentage
Gasoline only	585	25%
Gas HEV	573	25%
PHEV	388	17%
Diesel	71	3%
BEV	457	20%
FCEV	120	5%
PFCEV	118	5%
Total	**2,312**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 15 shows vehicle choice by prestige level. Standard brand vehicles were chosen the majority (84 percent) of the time.

Table 15: Residential Pretest — Vehicle Choice in DCE by Brand Type

Brand Type	Count	Percentage
Standard	1,933	84%
Premium	379	16%
Total	**2,312**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 16 shows vehicle choice by model year. New vehicles were chosen in half (50 percent) of experiments.

Table 16: Residential Pretest — Vehicle Choice in DCE by Model Year

Model Year	Count	Percentage
New	1,152	50%
Used (3 Years Old)	715	31%
Used (6 Years Old)	445	19%
Total	**2,312**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 17 summarizes the autonomy level choices in the autonomous vehicle discrete choice experiment by several categories. The greatest variation within categories was vehicle class and fuel type. Overall, respondents choose the base level of autonomy in nearly half (48 percent) of experiments.

Table 17: Residential Pretest: Autonomy Level Choice in DCE by Category

Category	Base	Level 3	Level 4	Level 5	Total
Car	50%	32%	10%	8%	100%
SUV	47%	30%	16%	7%	100%
Van	46%	31%	12%	11%	100%
Pickup	39%	31%	19%	12%	100%
Gasoline only	61%	24%	10%	5%	100%
Gas HEV	48%	36%	9%	8%	100%
PHEV	45%	33%	13%	9%	100%
Diesel	41%	33%	8%	18%	100%
BEV	37%	30%	16%	17%	100%
FCEV	40%	46%	10%	4%	100%
PFCEV	46%	37%	10%	7%	100%
Standard	48%	32%	12%	8%	100%
Premium	46%	30%	9%	14%	100%
New	46%	34%	10%	9%	100%
Used (3 Years Old)	46%	30%	15%	9%	100%
Used (6 Years Old)	54%	28%	10%	8%	100%
Overall	**48%**	**32%**	**12%**	**9%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Residential Pretest — Incentives

Incentives were offered to all respondents recruited through the address-based sampling frame who completed the survey. Research panel respondents were incentivized directly by Dynata using a proprietary compensation system.

Address-based respondents were given the option of receiving a $15 gift card from Amazon.com or Walmart. **Table 18** shows the distribution of incentive choices across the sample.

Table 18: Residential Pretest — Incentives

Gift Card Selection	Count	Percent
Selected Amazon	142	76%
Selected Walmart	25	14%
Declined	16	9%
Total	**183**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Residential Pretest — Respondent Feedback

At the end of the survey, all respondents were asked to provide feedback on the survey. While respondents were forced to write something, most respondents said they had no comment or simply said thank you. Some respondents said that they found the survey informative. Others expressed some dissatisfaction with the survey. The most common complaint was that the survey was too long: seventeen respondents stated this specifically. Some respondents desired more opportunities to write responses in text or answer "none of the above." Many respondents commented about issues covered in the survey that did not directly relate to the functionality of the survey. The most common subject of these comments was concerns about or dislike of alternative fuel vehicles. No other common themes were identified that would indicate widespread survey comprehension or completion challenges.

Residential Pretest — Recommended Changes to Survey Instruments and Procedures

Several recommendations for revisions to the residential survey instruments and procedures were made following the completion of the pretest. These are summarized below:

- The project team recommended expanding the vehicle database of the survey to fill in make and model gaps that were pointed out by respondents.
- To reduce ordering effects in the vehicle choice SP, the project team recommended randomizing the position of the reference vehicle, which is most closely based on the respondent's consideration set.
- The project team recommended changing refueling time to an alternative-specific variable in the vehicle choice SP, where it was previously a scenario variable.
- As many respondents sent emails inquiring about the status of their incentive, the project team recommended greater emphasis in the survey that dispensation of the incentives will take 10–12 weeks.

- The project team recommended including language in the invitation letter that if the survey was already completed by someone in the household, the letter may be disregarded.
- The observed pretest completion rate of 4.9 percent was higher than the 4 percent completion rate targeted for the full residential survey. The project team recommended making minor adjustments to the sampling plan to reflect the observed response rate in the calculation of survey invitations for the full launch.
- To reduce respondent burden, the project team recommended making several changes to the questions new to the 2024 edition of the survey, including:
    - Removing the question asking which autonomous ride-hail services the respondent had used.
    - Removing two statements from the AV attitude statements.
    - Removing the questions that ask respondents to compare their interest in owning an AV versus using autonomous ride-hail services.
    - Removing one statement when asking respondents how certain vehicle-to-grid scenarios would affect their EV consideration.

Residential ZEV Pretest

It was expected that the natural incidence of ZEV owners in the general California population would be too low to achieve a sufficient sample size for the ZEV owner section of the survey questionnaire. As a result, the project team developed a separate sampling plan for residential and commercial ZEV owners to achieve the necessary sample size for analysis. A separate set of questions was administered within the general questionnaire to residential and commercial respondents who own or operate one or more ZEVs. These general questions were augmented with ZEV specific questions for the ZEV owners participating in the survey. The following section describes the test administration results of the residential ZEV sampling frame. The targeted sample size for the residential ZEV pretest was set at 50 completed surveys.

Residential ZEV Pretest — Sampling

The survey population for the ZEV owner survey was all households in California with at least one registered light-duty ZEV — either a PHEV, a BEV, or a FCEV. The ABS sampling frame for the ZEV survey was the vehicle registration database of all ZEVs registered in California.

The team estimated the response rate for the proposed address-based recruitment to be 7 percent on average, with some variation expected by the region. This assumed response rate implied that 700 invitations would need to be distributed across the state to achieve 50 complete surveys. To ensure enough complete surveys from residential FCEV owners, those households were oversampled. **Table 19** presents the distribution of plugin (PHEV or BEV) owner households across the six regions, along with the corresponding number of invitations distributed to households in each region, while **Table 20** shows the same for FCEV-owners.

Table 19: Residential ZEV Pretest — Plugin Sampling Plan

Region	ZEV Owner Households Count	ZEV Owner Households Percentage	Invitations Distributed Count	Invitations Distributed Percentage
San Francisco	378,590	31%	153	31%
Los Angeles	586,896	47%	236	47%
San Diego	378,590	9%	45	9%
Sacramento	110,942	5%	26	5%
Central Valley	63,331	4%	20	4%
Rest of State	49,697	4%	20	4%
Total	**1,239,036**	**100%**	**500**	**100%**

Source: California Energy Commission analysis of California Department of Motor Vehicles data

Table 20: Residential ZEV Pretest — FCEV Sampling Plan

Region	ZEV Owner Households Count	ZEV Owner Households Percentage	Invitations Distributed Count	Invitations Distributed Percentage
San Francisco	3,210	25%	50	25%
Los Angeles	8,534	66%	131	66%
San Diego	473	4%	7	4%
Sacramento	509	4%	8	4%
Central Valley	127	1%	2	1%
Rest of State	103	1%	2	1%
Total	**12,956**	**100%**	**200**	**100%**

Source: California Energy Commission analysis of California Department of Motor Vehicles data

Residential ZEV Pretest — Summary of Recruitment and Data

In the four weeks after the pretest invitations were distributed, 56 respondents from the residential ZEV sampling frame entered the survey, and completed the questionnaire. This indicated a higher response and completion rate than was found in the general residential sampling frame. **Table 21** presents the incidence of completed surveys and the count of dropouts and disqualifications. Survey dropouts are respondents who began the survey but left the questionnaire before finishing, and disqualifications represent cases where respondents were disqualified from participating in the study based on their responses to the qualification questions. The overall completion rate was 8 percent, with the highest rate of completion in the San Francisco area and the lowest rate in the Central Valley.

Table 21: Residential ZEV Pretest — Response Summary by Region

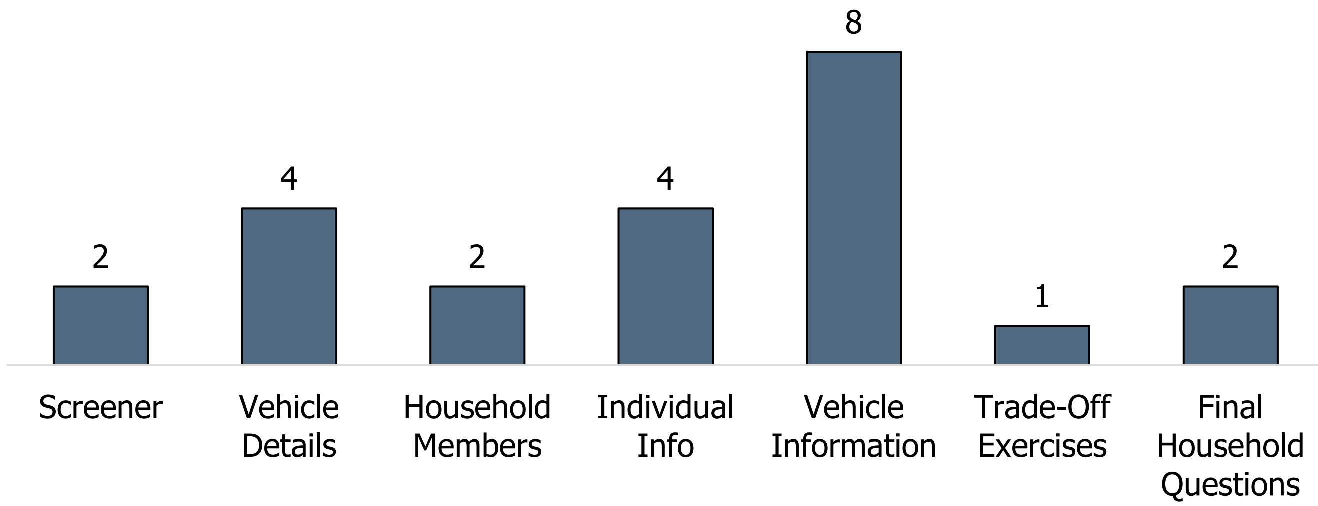
Survey Region	Invitations Count	Completes Count	Dropouts Count	Disqualifications Count	Total Logins Count	Response Rate (Completes) Percent
San Francisco	203	21	9	2	32	10.3%
Los Angeles	367	26	7	2	35	7.1%
San Diego	52	5	3	0	12	9.6%
Sacramento	34	2	3	0	5	5.9%
Central Valley	22	0	1	0	1	0%
Rest of State	22	2	0	0	2	9.1%
Total	**700**	**56**	**23**	**4**	**83**	**8%**

Source: 2024 California Vehicle Survey, California Energy Commission

Of the four respondents who were terminated from the survey, all indicated they do not participate in the household decision-making process when acquiring a new vehicle.

Figure 8 shows the locations in the survey where respondents dropped out during the pretest. The highest incidence of dropouts occurred at the vehicle information questions.

Figure 8: Residential ZEV Pretest — Dropout Locations



Source: 2024 California Vehicle Survey, California Energy Commission

Table 22 shows survey completion time statistics for the remaining respondents who finished the survey. Overall, the median completion time was longer than the median time of respondents in the general sampling frame. This longer completion time was because respondents in the ZEV sampling frame also completed the additional ZEV questionnaire nested within the general residential survey.

Table 22: Residential ZEV Pretest — Survey Duration

Minutes	Survey Duration
Minimum	8
Maximum	8,459
Median	39

Source: 2024 California Vehicle Survey, California Energy Commission

Most respondents included in the ZEV sampling frame reported owning at least one ZEV and completed the ZEV portion of the questionnaire. Of the 56 respondents from the ZEV sampling frame who completed the questionnaire, 54 reported owning at least one plug-in electric vehicle and 16 reported owning at least one hydrogen vehicle, while 3 respondents indicated they did not currently own a ZEV. In addition, some of the respondents from the general address-based and research panel sampling frames reported owning a ZEV. Of the 233 respondents from the general household and residential panel sampling frames who completed the study, 30 reported owning one or more ZEVs. As a result, 83 total respondents completed the ZEV portion of the questionnaire during the residential pretest. **Table 23** shows household-level ZEV ownership for the general sampling frame and the ZEV-owner sampling frame combined. Overall, 29 percent of the residential pretest samples reported owning a ZEV.

Table 23: Residential ZEV Sample Pretest — Fuel Type Ownership

Vehicle Type	ZEV Sample Ownership Count	ZEV Sample Ownership Percent	General Sample Ownership Count	General Sample Ownership Percentage	Overall Ownership Count	Overall Ownership Percent
PHEV	12	21.4%	9	3.9%	21	7.3%
BEV	32	57.1%	24	10.3%	56	19.4%
FCEV	16	28.6%	0	0.0%	16	5.5%
Do Not Own PHEV/BEV	3	5.4%	203	87.1%	206	71.3%
Total	**56**	**100%**	**233**	**100%**	**289**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Note: Some respondents reported owning more than one type of ZEV.

Residential ZEV Pretest — Incentives

Incentives were offered to all respondents who completed the survey. Respondents were given the option of receiving a $15 electronic gift card from Amazon.com or Walmart. **Table 24** shows the distribution of incentive selection.

Table 24: Residential ZEV Pretest — Incentives

Gift Card Selection	Count	Percentage
Selected Amazon	52	93%
Selected Walmart	2	4%
Declined	2	4%
Total	**56**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Residential ZEV Pretest — Recommended Changes to Survey Instruments and Procedures

The observed pretest completion rate of 8 percent was higher than the 7 percent completion rate targeted for the full residential ZEV survey. The project team recommended making minor adjustments to the sampling plan to reflect the observed response rate in the calculation of survey invitations for the full launch.

Commercial Pretest

The commercial survey was administered to the population of California fleet managers using one sampling frame: a general commercial sampling frame of businesses with at least one registered vehicle in California from S&P Global.

The targeted sample size for the commercial pretest survey was 200 completed surveys from the address-based sampling frame.

As in the residential survey, a separate sampling frame was used to target commercial establishments with a ZEV registered in California to purposefully oversample the number of ZEV owners in the dataset. This section documents the results of the survey administration to the general commercial sampling frame. The results of the commercial ZEV sampling frame are documented in a subsequent section of this chapter.

Commercial Pretest — Address-Based Sampling

The project team worked with S&P Global (S&P) to select a random sample of commercial establishments with light-duty (under 10,000 lbs. gross weight) vehicles registered in California, stratified by region and fleet size. S&P maintains a vehicle database built using vehicle registration data from the California Department of Motor Vehicles (DMV) and classifies each vehicle as residential or commercial based on information about the entity to which the vehicle is registered. S&P is also able to estimate the number of light-duty vehicles registered to each establishment, providing a count of establishments by fleet size. The S&P frame contains every vehicle registered in California and is updated monthly.

The commercial pretest sampling frame was stratified by the six study regions described in **Table 4** above, as well as by five fleet size categories. **Table 25** presents the distribution of establishments by fleet size and region, as provided by S&P.

Table 25: Commercial Pretest — Distribution of Commercial Fleets by Fleet Size and Region

Region	1 Vehicle Fleet	2 Vehicle Fleet	3–5 Vehicle Fleet	6–9 Vehicle Fleet	10+ Vehicle Fleet	Region Distribution
San Francisco	10%	3%	3%	1%	2%	**19%**
Los Angeles	28%	8%	7%	2%	3%	**47%**
San Diego	5%	1%	1%	1%	1%	**9%**
Sacramento	3%	1%	1%	0%	1%	**6%**
Central Valley	5%	2%	2%	1%	1%	**10%**
Rest of State	4%	1%	1%	1%	1%	**8%**
Fleet Size Distribution	**54%**	**16%**	**15%**	**6%**	**8%**	**100%**

Source: 2024 S&P Global

The team estimated the response rate for the proposed commercial address-based recruitment to be 3 percent on average, with some variation expected by region and fleet size. To achieve the desired pretest sample size of 200 address-based sampling completes, RSG distributed 6,700 survey invitations to commercial establishments in May 2024. **Table 26** presents the distribution of postcards by fleet size and region for the commercial pretest.

Table 26: Commercial Pretest — Distribution of Survey Invitations by Fleet Size and Region

Survey Region	1 Vehicle Fleet	2 Vehicle Fleet	3–5 Vehicle Fleet	6–9 Vehicle Fleet	10+ Vehicle Fleet	Region Distribution
San Francisco	10%	3%	3%	1%	1%	**19%**
Los Angeles	27%	7%	7%	2%	3%	**46%**
San Diego	5%	1%	1%	1%	1%	**10%**
Sacramento	3%	1%	1%	1%	1%	**6%**
Central Valley	4%	1%	2%	1%	1%	**10%**
Rest of State	4%	1%	1%	1%	1%	**8%**
Fleet Size Distribution	**54%**	**16%**	**16%**	**7%**	**8%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial Pretest — Summary of Recruitment and Data

The commercial pretest collected complete surveys from 314 respondents (**Table 27**). The number of complete surveys for the address-based sampling frame was substantially greater than the 200 expected completes for the pretest phase of the study.

Table 27: Commercial Pretest — Targeted Completes and Actual Completes by Sampling Frame

Sampling Frame	Targeted Pretest Surveys	Actual Pretest Surveys
Address-based	200	314
Total	**200**	**314**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 28 presents the counts and percentages of completed commercial surveys by region. The table compares the address-based sampling figures to the targeted proportion of completes as specified in the sampling plan for the pretest launch.

Table 28: Commercial Pretest — Address-Based Sampling Completes by Region

Region	Completes Count	Share of Completes Percentage	Region Target Percentage
San Francisco	60	19%	19%
Los Angeles	122	39%	46%
San Diego	35	11%	10%
Sacramento	25	8%	6%
Central Valley	38	12%	10%
Rest of State	34	11%	8%
Total	**314**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 29 summarizes the fleet size reported by 314 fleet managers who completed the survey and compare these figures to the targeted share.

Table 29: Commercial Pretest — Address-Based Sampling Completes by Fleet Size

Vehicle Fleet Size	Completes Count	Share of Completes Percentage	Fleet Size Target Percentage
0 Vehicles	6	2%	0%
1 Vehicle	85	27%	54%
2 Vehicles	67	21%	16%
3–5 Vehicles	78	25%	16%
6–9 Vehicles	37	12%	7%
10 or More Vehicles	41	13%	8%
Total	**314**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 30 presents the incidence of completed surveys and the count of dropouts and disqualifications. Survey dropouts are respondents who began the survey but left the questionnaire before finishing, and disqualifications represent cases where respondents were disqualified from participating in the study based on their responses to the qualification questions. The observed completion rate was 4.7 percent on average, with the highest rate of completion in the Sacramento area (6.3 percent) and the lowest rate of completion (3.9 percent) in the Los Angeles region.

Table 30: Commercial Pretest — ABS Response Summary by Region

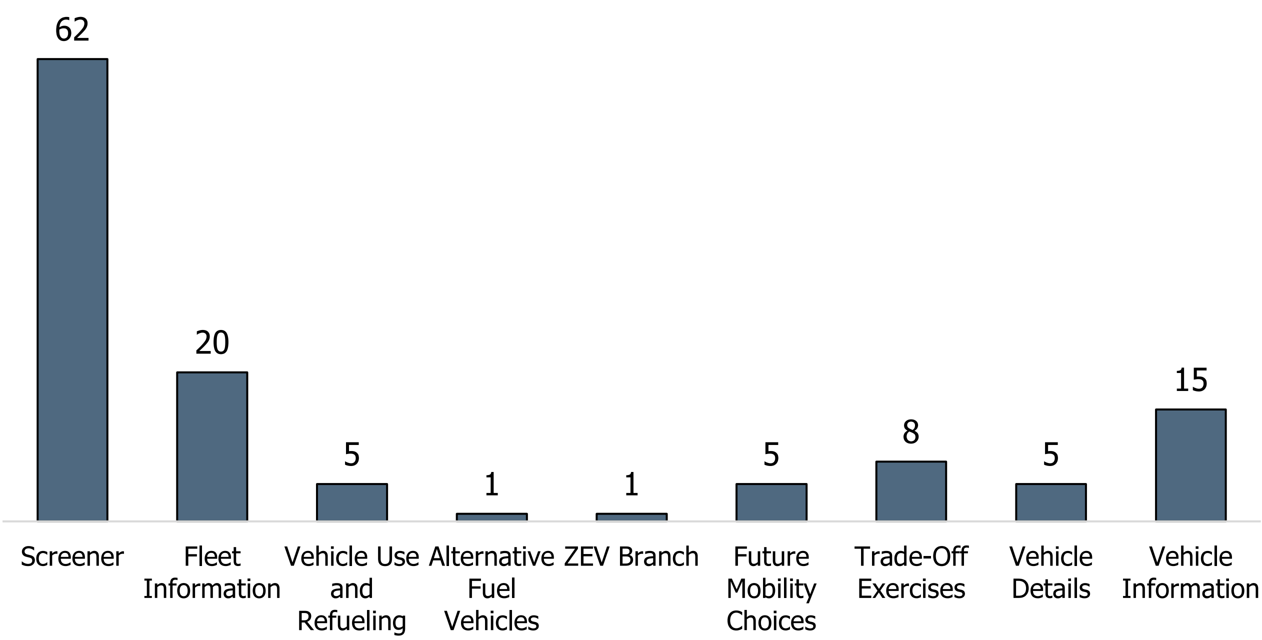
Survey Region	Invitations Count	Completes Count	Dropouts Count	Disqualifications Count	Total Logins Count	Response Rate Percent
San Francisco	1,300	60	24	12	96	4.6%
Los Angeles	3,100	122	60	21	203	3.9%
San Diego	650	35	16	6	57	5.4%
Sacramento	400	25	3	4	32	6.3%
Central Valley	700	38	12	7	57	5.4%
Rest of State	550	34	16	8	58	6.2%
Total	**6,700**	**314**	**131**	**58**	**503**	**4.7%**

Source: 2024 California Vehicle Survey, California Energy Commission

Of the 58 respondents who were disqualified from taking the survey, 30 indicated that their type of organization was a car rental company, a taxicab company or a government agency, 24 indicated there were no light-duty vehicles at their location, and 4 indicated none of their company's locations had light-duty vehicles.

Figure 9 shows the locations in the survey where respondents dropped out of the questionnaire; most respondents dropped out on the introduction page and decision-maker page at the beginning of the survey.

Figure 9: Commercial Pretest — Dropout Locations



Source: 2024 California Vehicle Survey, California Energy Commission

Table 31 shows the duration statistics for the 314 general sampling frame respondents who completed the questionnaire. As with the residential survey, the median completion times are relatively long but not unexpected considering the length and complexity of the questionnaire.

Table 31: Commercial Pretest — Completion Time Statistics

Minutes	Survey Duration (minutes)
Minimum	7
Maximum	1,948
Median	27

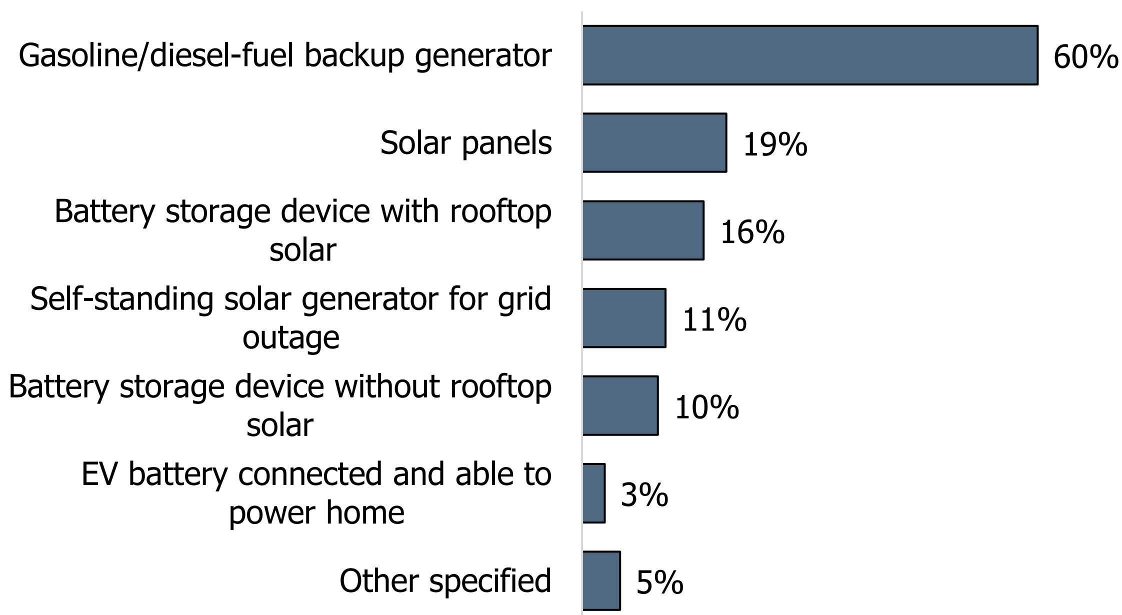
Source: 2024 California Vehicle Survey, California Energy Commission

Commercial Pretest — Review of New Questions

This section examines the response to each question and for which the project team suggested making a change for the full implementation of the survey.

Respondents were asked if they had a backup energy source, and 17 percent did. Those with backup energy sources were asked to specify what kind they had (**Figure 10**), and more than half (60 percent) had a gasoline or diesel backup generator. One respondent who selected "Other" specified they used a natural gas generator, so the project team recommended including natural gas and propane in the fuel generator option in the full launch of the CVS.

Figure 10: Commercial Pretest — Backup Energy Source Type (Select All That Apply)



Source: 2024 California Vehicle Survey, California Energy Commission

Commercial Pretest — Discrete Choice Experiment Results

While the sample size of the pretest was too small to finalize discrete choice models, this section shares high-level statistics about which vehicles were chosen in each discrete choice experiment.

Table 32 shows how many times each vehicle was chosen in the vehicle type discrete choice experiment by position. Vehicle 1 was based on the respondent's consideration set and was chosen 72 percent of the time. While it is not surprising the reference vehicle is chosen more frequently than alternatives, RSG recommended randomizing the location of the reference vehicle in the discrete choice experiments to avoid potential ordering effects.

Table 32: Commercial Pretest — Vehicle Choice in SP

Choice	Count	Percentage
Reference Vehicle	2,172	72%
Vehicle 2	425	14%
Vehicle 3	246	8%
Vehicle 4	157	5%
Total	**3,000**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 33 through **Table 36** show choice by vehicle class, fuel type, prestige level, and model year. However, because these variables depended on the vehicles in each respondent's consideration set, the attribute levels are not presented an even number of times across the sample.

Table 33 shows that cars were chosen in only 19 percent of experiments.

Table 33: Commercial Pretest — Vehicle Choice in DCE by Vehicle Class

Vehicle Class	Count	Percentage
Car-Subcompact	66	2%
Car-Compact	125	4%
Car-Midsize	257	9%
Car-Large	79	3%
Car-Sport	46	2%
Car Subtotal	*573*	*19%*
SUV-Subcompact	54	2%
SUV-Compact	101	3%
SUV-Midsize	379	13%
SUV-Large	168	6%
SUV Subtotal	*702*	*23%*
Van-Compact	196	7%
Van-Standard	344	11%
Van Subtotal	*540*	*18%*
Pickup-Compact	326	11%
Pickup-Standard	859	29%
Pickup Subtotal	*1,185*	*40%*
Total	3,000	100%

Source: 2024 California Vehicle Survey, California Energy Commission

Table 34 shows vehicle choice by fuel type. Gasoline only vehicles were chosen in more than one-third (35 percent) of experiments.

Table 34: Commercial Pretest — Vehicle Choice in DCE by Fuel Type

Fuel Type	Count	Percentage
Gasoline only	1,054	35%
Gas HEV	576	19%
PHEV	330	11%
Diesel	296	10%
BEV	506	17%
FCEV	97	3%
PFCEV	141	5%
Total	**3,000**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 35 shows vehicle choice by prestige level. Standard brand vehicles were chosen most (84 percent) of the time.

Table 35: Commercial Pretest — Vehicle Choice in DCE by Brand Type

Brand Type	Count	Percentage
Standard	2,518	84%
Premium	482	16%
Total	**3,000**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 36 shows vehicle choice by model year. New vehicles were chosen most frequently, with respondents choosing them in more than half (58 percent) of experiments.

Table 36: Commercial Pretest — Vehicle Choice in DCE by Model Year

Model Year	Count	Percentage
New	1,725	58%
Used (3 Years Old)	847	28%
Used (6 Years Old)	428	14%
Total	**3,000**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 37 summarizes the autonomy level choices in the AV discrete choice experiments by several categories. The greatest variation within categories was vehicle class and fuel type. Overall, respondents choose the base level of autonomy in more than half (55 percent) of experiments.

Table 37: Commercial Pretest: Autonomy Level Choice in DCE by Category

Category	Base	Level 3	Level 4	Level 5	Total
Car	47%	31%	10%	12%	100%
SUV	63%	21%	8%	8%	100%
Van	42%	27%	12%	18%	100%
Pickup	63%	24%	5%	8%	100%
Gasoline only	70%	17%	6%	8%	100%
Gas HEV	45%	33%	11%	11%	100%
PHEV	51%	29%	10%	11%	100%
Diesel	62%	26%	7%	5%	100%
BEV	41%	23%	13%	23%	100%
FCEV	47%	18%	18%	16%	100%
PFCEV	39%	47%	7%	8%	100%
Standard	58%	25%	8%	9%	100%
Premium	41%	23%	13%	23%	100%
New	56%	23%	9%	12%	100%
Used (3 Years Old)	53%	30%	9%	9%	100%
Used (6 Years Old)	56%	22%	10%	13%	100%
Overall	**55%**	**25%**	**9%**	**11%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial Pretest — Incentives

Commercial fleet respondents recruited through the address-based sampling frame were offered an incentive of a $40 gift card to Amazon.com or Walmart. **Table 38** shows the distribution of survey incentive choices.

Table 38: Commercial Pretest — Incentives

Gift Card Selection	Count	Percentage
Selected Amazon	261	83%
Selected Walmart	37	12%
Declined	16	5%
Total	**314**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial Pretest — Respondent Feedback

At the end of the survey, all respondents were asked to provide feedback on the survey. While respondents were forced to write something, most respondents said they had no comment or simply said thank you. Eight respondents stated the survey was too long. Some respondents detailed the specific vehicle needs of their businesses. Most other comments related to opinions on alternative fuel vehicles or autonomous vehicles. Some of these comments spoke of the technologies in a positive light, while most others expressed skepticism or dislike of the technologies. No other common themes were identified that would indicate widespread survey comprehension or completion challenges.

Commercial Pretest — Recommended Changes to Survey Instruments and Procedures

Several recommendations for revisions to the commercial survey instruments and procedures were made following the completion of the pretest. These are summarized below:

- The project team recommended expanding the vehicle database of the survey to fill in make and model gaps that were pointed out by respondents.
- To reduce ordering effects in the vehicle choice SP, the project team recommended randomizing the position of the reference vehicle, which is most closely based on the respondent's consideration set.
- The project team recommended changing refueling time to an alternative-specific variable in the vehicle choice SP, where it was previously a scenario variable.
- As many respondents sent emails inquiring about the status of their incentive, the project team recommended greater emphasis in the survey that dispensation of the incentives will take 10–12 weeks.
- The project team recommended including language in the invitation letter that if the survey was already completed by someone at the business, the letter may be disregarded.
- The observed pretest completion rate of 4.7 percent was higher than the 3 percent completion rate targeted for the full commercial survey. The project team recommended making minor adjustments to the sampling plan to reflect the observed response rate in the calculation of survey invitations for the full launch.
- An error was found in the survey that allowed six respondents to complete the survey even though they had no commercial vehicles. The project team recommended changing survey logic around the personal fleet question to remedy this error.
- The survey team recommended changing "hover" to "click" in a few questions where extra information can be seen by clicking a link.
- The survey team recommended adding a question asking for the purchase price of each vehicle purchased in the previous two years to match a similar question in the residential survey.

Commercial ZEV Pretest

It was expected that the natural incidence of ZEV owners in the general California commercial establishment population would be too low to achieve a sufficient sample size for the ZEV owner section of the survey questionnaire. As a result, the project team developed a separate sampling plan for commercial ZEV owners to achieve the sample size desired for analysis. The following section describes the test administration results of the commercial ZEV sampling frame. The targeted sample size for the residential ZEV pretest was 50 complete surveys.

Commercial ZEV Pretest — Address-Based Sampling

The survey population for the ZEV owner survey was all California establishments with at least one registered light-duty ZEV — either a PHEV, a BEV, or a FCEV. The sampling frame for the ZEV survey was the vehicle registration database of all ZEVs registered in California.

The team estimated the response rate for the proposed address-based recruitment to be 2.75 percent on average, with some variation expected by the survey region. This assumed response rate implied that 1,800 invitations would need to be distributed across the state to achieve 50 complete surveys. To ensure enough complete surveys from commercial FCEV owners, those businesses were oversampled. **Table 39** presents the distribution of plug-in (PHEV or BEV) owner establishments across the six regions along with the corresponding number of invitations distributed to establishments in each region, while **Table 40** shows the same for FCEV-owner establishments.

Table 39: Commercial ZEV Pretest — Plug-In Sampling Plan

Region	Plug-In Owner Establishments Count	Plug-In Owner Establishments Percentage	Invitations Distributed Count	Invitations Distributed Percentage
San Francisco	35,360	28%	419	28%
Los Angeles	63,773	50%	756	50%
San Diego	10,743	8%	127	8%
Sacramento	6,157	5%	73	5%
Central Valley	6,215	5%	74	5%
Rest of State	4,336	3%	51	3%
Total	**126,584**	**100%**	**1500**	**100%**

Source: California Energy Commission analysis of California Department of Motor Vehicles data

Table 40: Commercial ZEV Pretest — FCEV Sampling Plan

Region	FCEV Owner Establishments Count	FCEV Owner Establishments Percentage	Invitations Distributed Count	Invitations Distributed Percentage
San Francisco	212	21%	62	21%
Los Angeles	670	66%	198	66%
San Diego	75	7%	22	7%
Sacramento	43	4%	13	4%
Central Valley	11	1%	3	1%
Rest of State	7	1%	2	1%
Total	**1,018**	**100%**	**300**	**100%**

Source: California Energy Commission analysis of California Department of Motor Vehicles data

Commercial ZEV Pretest — Summary of Recruitment and Data

During the test phase of the commercial survey, 134 respondents from the commercial ZEV sampling frame entered the survey and 62 completed the questionnaire. **Table 41** presents the incidence of completed surveys and the counts of dropouts and disqualifications. The overall completion rate was modest (3.4 percent).

Table 41: Commercial ZEV Pretest — Response Summary by Region

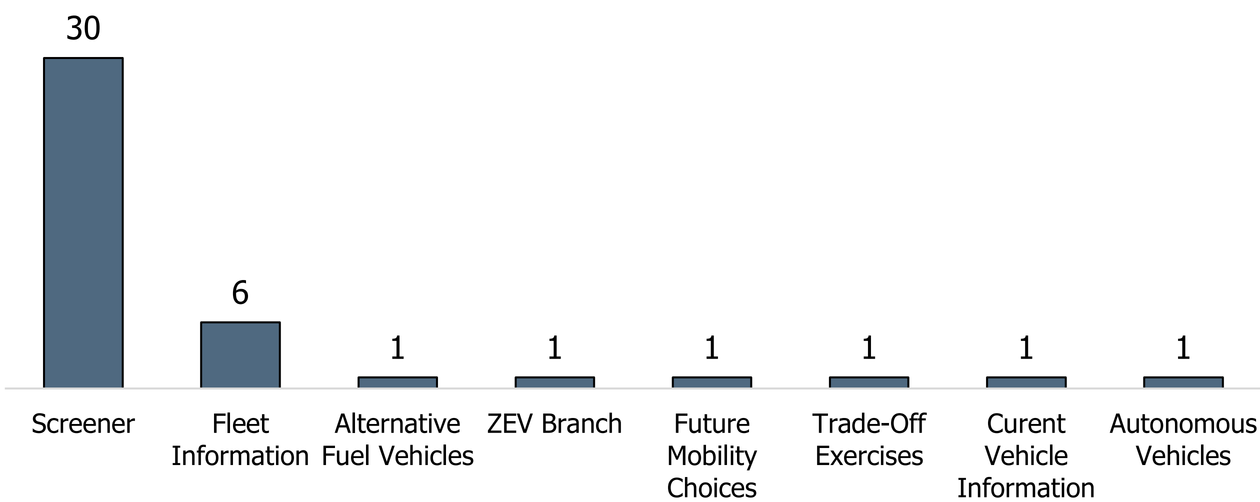
Region	Invitations Count	Completes Count	Dropouts Count	Disqualifications Count	Total Logins Count	Response Rate (Completes) Percentage
San Francisco	481	10	17	10	37	2.1%
Los Angeles	954	41	18	12	71	4.3%
San Diego	149	5	4	1	10	3.4%
Sacramento	19	2	4	2	8	2.3%
Central Valley	77	3	1	1	5	3.4%
Rest of State	53	1	1	1	3	1.9%
Total	**1,800**	**62**	**45**	**27**	**134**	**3.4%**

Source: 2024 California Vehicle Survey, California Energy Commission

Of the 27 respondents who were disqualified from taking the survey, 18 indicated that their type of organization was a car rental company, a taxicab company or a government agency, 7 indicated there were no light-duty vehicles at their location, and 4 indicated none of their company's locations had light-duty vehicles.

Figure 11 shows the eight most common locations in the survey where the 62 respondents who started without finishing dropped out of the questionnaire. The highest incidence of dropouts occurred at the question that asked about whether they were the vehicle decision maker in their organization.

Figure 11: Commercial ZEV Pretest — Dropout



Source: 2024 California Vehicle Survey, California Energy Commission

Table 42 summarizes the reported fleet size of the 61 fleet managers who completed the survey from commercial ZEV sampling frame. Most respondents reported having only one or two vehicles in their fleet.

Table 42: Commercial ZEV Survey — Fleet Size

Household Vehicles	Completes Count	Share of Completes Percentage
1 vehicle	20	33%
2 vehicles	17	28%
3–5 vehicles	10	17%
6–9 vehicles	3	5%
10+ vehicles	11	18%
Total	**61**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Of the 61 fleet managers who were recruited using the ZEV sampling frame and completed the survey, 41 reported owning at least one ZEV. Of the 314 fleet managers who were recruited using the general commercial sampling frame and completed the survey, 36 reported owning at least one ZEV. As a result, 77 total respondents completed the ZEV portion of the questionnaire during the commercial vehicle pretest. **Table 43** shows business-level ZEV ownership for the general sampling frame and the ZEV-owner sampling frame combined. Overall, 21 percent of the commercial pretest samples reported owning a ZEV.

Table 43: Commercial ZEV Pretest — Establishment-Level ZEV Ownership (All Commercial Respondents)

Vehicle Type	ZEV Sample Ownership *Count*	ZEV Sample Ownership *Percentage*	General Sample Ownership *Count*	General Sample Ownership *Percentage*	Overall Ownership *Count*	Overall Ownership *Percentage*
PHEV	5	8.2%	11	3.5%	16	4.3%
BEV	34	55.7%	29	9.2%	63	16.8%
FCEV	6	9.8%	0	0.0%	6	1.6%
Do Not Own PHEV/BEV	20	32.8%	278	88.5%	298	79.5%
Total Respondents	**61**	**100%**	**314**	**100%**	**375**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Note: Some respondents reported owning more than one type of ZEV

Table 44 shows the duration statistics for the 61 ZEV sampling frame respondents who completed the questionnaire.

Table 44: Commercial Pretest — Completion Time Statistics

Minutes	Survey Duration (minutes)
Minimum	11
Maximum	256
Median	27

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial ZEV Pretest — Review of New Questions

Two new questions were added to the ZEV section of the commercial survey in 2024. Respondents were asked if they were interested in being able to charge their business's physical location in the event of a blackout, and 60 percent were. Respondents were asked if they were interested in being able to discharge the battery of one vehicle to charge another, and again 60 percent were.

Commercial ZEV Pretest — Incentives

Incentives were offered to all respondents who completed the commercial establishment survey. Respondents were given the option of receiving a $40 electronic gift card from Amazon.com or Walmart. **Table 45** shows the distribution of survey incentive choices for respondents recruited through the commercial ZEV sampling frame.

Table 45: Commercial ZEV Pretest — Incentives

Gift Card Selection	Count	Percentage
Selected Amazon	56	92%
Selected Walmart	5	8%
Total	**61**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial ZEV Pretest — Recommended Changes to Survey Instruments and Procedures

The observed pretest completion rate of 3.4 percent was higher than the 2.75 percent completion rate targeted for the full commercial survey. The project team recommended making minor adjustments to the sampling plan to reflect the observed response rate in the calculation of survey invitations for the full launch.

CHAPTER 6: Survey Recruitment Implementation

Pretest survey results lead to some modifications in residential and commercial survey instruments, but both surveys continued to rely on stratified random sampling approach, with minor modifications to estimated response rates.

Residential Survey

The residential survey component of the 2024 CVS was a comprehensive study designed to gather data on household vehicle ownership, usage patterns, and future purchasing intentions across the state. The survey used a stratified random sampling approach that aimed to collect responses from 3,500 households. The survey employed address-based sampling and online panel recruitment methods and included incentives to encourage participation.

The residential questionnaire collected information about a wide range of topics, including household composition and demographics, current vehicle inventories, vehicle preferences, and attitudes toward alternative fuel vehicles and autonomous technologies.

Residential Sampling Plan

The sampling plan describes the survey population, sampling frame, and methodology for the residential survey.

Survey Population

The population for the residential vehicle survey was individual households in California. Using this population matches the California Energy Commission forecasting model that operates at a household level.

Sampling Frame

The sampling frame was split between address-based sampling (ABS) and online panel participants. The United States Postal Service (USPS) Computerized Delivery Sequence (CDS) file, which provides and continually updates all mailing addresses served by the USPS, serves as the ABS sampling frame. The ABS sample was supplemented by a sample from Dynata, a private online market research firm that maintains a large and diverse panel of residents across California.

Sampling Methodology

The survey team used a stratified random sampling approach for the residential vehicle survey. The team randomly selected households by address at the county level such that invitations to participate were proportional to the population of each county in the state. Estimates of the number of households in each county come from the 2022 American Community Survey (ACS) five-year estimates. The number and percentage of households in each county, along with the approximate number of survey invitations that will be distributed in each county, are presented in **Table 46** through **Table 52** below. The counties were grouped into six geographic regions, and responses were monitored to ensure adequate representation from each of the six regions of interest. The sampling methodology for the panel supplied by Dynata was less sophisticated but broadly represented the general population of California.

Table 46: Household Counts by Survey Region

Region	Households	Percentage of State
San Francisco	2,767,439	20.8%
Los Angeles	6,161,960	46.3%
San Diego	1,149,157	8.6%
Sacramento	928,298	7.0%
Central Valley	1,319,872	9.9%
Rest of State	989,096	7.4%
Total	13,315,822	100%

Source: 2022 American Community Survey

Table 47: Household Counts by County — San Francisco Region

County	Households	Percentage of Region's Households	Assuming 4.5% Response Rate, Expected Number of Invitations
Alameda	585,818	21.2%	1,584
Contra Costa	408,537	14.8%	1,105
Marin	103,709	3.7%	280
Napa	49,218	1.8%	133
San Francisco	360,842	13.0%	976
San Mateo	264,323	9.6%	715
Santa Clara	650,352	23.5%	1,758
Solano	154,987	5.6%	419
Sonoma	189,653	6.9%	513
Total	**2,767,439**	**100.0%**	**7,482**

Source: 2022 American Community Survey

Table 48: Household Counts by County — Los Angeles Region

County	Households	Percentage of Region's Households	Assuming 4.5% Response Rate, Expected Number of Invitations
Imperial	47,024	0.8%	127
Los Angeles	3,363,093	54.6%	9,092
Orange	1,066,286	17.3%	2,883
Riverside	749,976	12.2%	2,028
San Bernardino	659,928	10.7%	1,784
Ventura	275,653	4.5%	745
Total	**6,161,960**	**100.0%**	**16,659**

Source: 2022 American Community Survey

Table 49: Household Counts by County — San Diego Region

County	Households	Percentage of Region's Households	Assuming 4.5% Response Rate, Expected Number of Invitations
San Diego	1,149,157	100.0%	3,107
Total	**1,149,157**	**100.0%**	**3,107**

Source: 2022 American Community Survey

Table 50: Household Counts by County — Sacramento Region

County	Households	Percentage of Region's Households	Assuming 4.5% Response Rate, Expected Number of Invitations
El Dorado	75,190	8.1%	203
Placer	152,537	16.4%	412
Sacramento	563,856	60.7%	1,524
Sutter	33,041	3.6%	89
Yolo	76,107	8.2%	206
Yuba	27,567	3.0%	75
Total	**928,298**	**100.0%**	**2,510**

Source: 2022 American Community Survey

Table 51: Household Counts by County — Central Valley Region

County	Households	Percentage of Region's Households	Assuming 4.5% Response Rate, Expected Number of Invitations
Fresno	318,322	24.1%	861
Kern	277,499	21.0%	750
Kings	43,594	3.3%	118
Madera	43,857	3.3%	119
Merced	82,760	6.3%	224
San Joaquin	237,423	18.0%	642
Stanislaus	175,747	13.3%	475
Tulare	140,670	10.7%	380
Total	**1,319,872**	**100.0%**	**3,568**

Source: 2022 American Community Survey

Table 52: Household Counts by County — Rest of State Region

County	Households	Percentage of Region's Households	Assuming 4.5% Response Rate, Expected Number of Invitations
Alpine	435	0.0%	1
Amador	15,745	1.6%	43
Butte	83,319	8.4%	225
Calaveras	17,198	1.7%	46
Colusa	7,432	0.8%	20
Del Norte	9,530	1.0%	26
Glenn	9,742	1.0%	26
Humboldt	54,495	5.5%	147
Inyo	7,849	0.8%	21
Lake	26,487	2.7%	72
Lassen	8,925	0.9%	24
Mariposa	7,597	0.8%	21
Mendocino	34,557	3.5%	93
Modoc	3,403	0.3%	9
Mono	5,473	0.6%	15
Monterey	130,973	13.2%	354
Nevada	41,415	4.2%	112
Plumas	8,104	0.8%	22
San Benito	19,852	2.0%	54
San Luis Obispo	108,099	10.9%	292
Santa Barbara	148,032	15.0%	400
Santa Cruz	96,487	9.8%	261
Shasta	71,107	7.2%	192
Sierra	1,135	0.1%	3
Siskiyou	18,768	1.9%	51
Tehama	24,623	2.5%	67
Trinity	5,483	0.6%	15
Tuolumne	22,831	2.3%	62
Total	**989,096**	**100.0%**	**2,674**

Source: 2022 American Community Survey

Recruitment Methodology

Respondents who were recruited into the survey with the ABS sample were contacted using a two-staged, mail-based approach. First, a postcard invitation (4.25” by 5.5”) was mailed to adult residents of individual households. RSG designed a two-sided, full-color postcard to use for the invitation. The postcard contains a brief introduction to the project, information about the incentives offered for completing the survey, a URL and password to access the survey online, and a project email account that respondents may write to in case they need to secure any assistance to complete the survey. The information on the postcard was provided in both English and Spanish.

A reminder letter was sent to recruited households one to two weeks after the original postcard invitation. The letters were sealed in custom envelopes that matched the visual aesthetic of the project and contained a letter with a link to the survey with similar information to the postcard. RSG has found that this two-stage process with different invitation types improves participation rates when compared to studies where an initial invitation postcard and a reminder postcard are used. This approach was successfully implemented in the 2024 CVS Pretest and resulted in a response rate of more than 4.5 percent for the household vehicle survey. All printed materials and online graphics use consistent visual elements, including survey titles and description, color scheme, fonts, logos, and picture graphics. The intended effect of this coordination is to connect invitation and reminder materials with the online survey instrument.

The California Energy Commission undertook printing, processing and mailing recruitment material for the household pretest survey, and the California Office of State Publishing undertook printing, processing, and mailing the recruitment materials for the main household survey. Full designs of the invitation postcard and letter can be found in "Appendix D: Recruitment Materials."

RSG also contacted respondents who had started the web survey and not completed it by using the email that respondents provided in the survey instrument. These respondents received one or two reminder e-mails encouraging them to complete the survey.

Online panel members were recruited via email sent directly by Dynata. Panelists were able to enter the survey through customized links provided by Dynata that limits respondents to taking the survey once.

Data Retrieval

RSG offered a fully web-based retrieval instrument for the 2024 CVS. The survey invitation included a URL for completing the survey online, along with a unique household-specific password. The password was consistent on initial and reminder invitations, so participation can be accurately monitored across the sample frame. The URL took respondents to the survey website where they will be able to enter the password printed on the invitation and begin the survey.

The survey instrument was provided in English and Spanish. RSG worked with a professional translation vendor to translate and QA/QC the survey questions and supplemental information. Respondents were able to select their preferred language on the first screen of the survey.

Sample Size

The targeted sample size for the residential vehicle survey is 3,500 households, including valid responses from the pretest and the main survey. While the baseline household survey will target 3,500 responses, additional responses were collected through the household ZEV sampling frame (described in more detail below), which increased the total household survey sample size to more than 4,000 participants. RSG designed the household split sample to meet the targeted number of complete surveys. The target for the ABS sampling approach was 1,800 completed responses with postcard and letter reminders, and the remainder was to be collected through Dynata's online panel. Pretest survey collected 183 responses via ABS.

Based on the project team's experience from the 2024 CVS Pretest and other household travel surveys, the anticipated response rate for the ABS mailed based approach was 4.5 percent. As a result, invitations were sent to about 36,000 households to achieve the targeted number of complete surveys. The total sample size of 3,582 households results in a sampling margin of error of about 1.66 percent at the state level, at the 95 percent confidence level.

Incentives

An incentive in the form of a $15 eGift card, redeemable at either Amazon.com or Walmart, was offered to participants recruited through the ABS sampling frame who successfully completed the residential vehicle survey. RSG worked with the team's subcontractor, SourceOne Communications, and the CEC to develop and implement an acceptable incentive protocol that was designed to improve the efficiency of data collection and ensure participation from populations that are less likely to respond to the survey.

Respondents recruited through the online panel were not eligible to receive the incentive; Dynata uses its own incentive structure, the cost of which is included within the per-complete fee.

Table 53 shows incentive selection for all residential respondents. Research panel respondents were compensated separately by Dynata. Six percent (6 percent) of eligible respondents chose to decline the survey incentive.

Table 53: Residential Survey — Incentive Distribution

Incentive Status	Count	Total Percentage	Eligible Percentage
Dynata Compensation	1,754	43%	N/A
Selected Amazon.com	1,879	46%	81%
Selected Walmart	287	7%	12%
Declined Incentive	139	3%	6%
Total	**4,059**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Residential Response Rates

The project team updated the number of survey invitations distributed to each region using the overall response rate observed in the residential survey pretest launch. The initial sampling plan, consisting of 87,500 invitations distributed proportionally to the population of each county, was adjusted down to 36,000 to reflect the high observed response rates from the pretest. At the end of the data collection period, a supplemental 7,500 invitations were distributed to ensure sample targets were met. Table 54 shows invitation counts and response rates for each wave by region.

Table 54: Residential ABS Response Rates by Region

Region	Pretest	Main	Supplement	Total	Responses	Response Rate
San Francisco	779	7,482	1,430	9,691	434	4.5%
Los Angeles	1,735	16,659	3,280	21,674	747	3.4%
San Diego	324	3,107	650	4,081	177	4.3%
Sacramento	261	2,510	500	3,271	158	4.8%
Central Valley	372	3,568	1,140	5,080	155	3.1%
Rest of State	279	2,674	500	3,453	157	4.5%
Total	**3,750**	**36,000**	**7,500**	**47,250**	**1,828**	**3.9%**

Source: 2024 California Vehicle Survey, California Energy Commission

RSG worked with Dynata, a targeted online research panel provider, to collect the remaining 1,754 survey responses required to achieve the overall sample target of 3,500 completed residential surveys. Dynata maintains a prescreened panel of consumers across the United States. Panel members can be targeted by geography of residence or other targeted demographic information provided by participants during enrollment and subsequent profile updates. Dynata conducts regular data audits to ensure panels are composed of real people with robust, continually refreshed profiles. Panel respondents were sampled at the regional level to meet the geographic sampling objectives of the survey. **Table 55** shows the targeted percentage of completed surveys and the projected numbers of completed surveys, by region.

Table 55: Residential Panel Responses by Region

Region	Target	Target Share	Responses	Response Share
San Francisco	357	21%	345	20%
Los Angeles	782	46%	923	53%
San Diego	153	9%	128	7%
Sacramento	119	7%	149	8%
Central Valley	170	10%	129	7%
Rest of State	119	7%	80	5%
Total	**1,700**	**100%**	**1,754**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Residential ZEV Survey

The Energy Commission conducts analysis of DMV registered vehicle data to distribute LDV population, including ZEVs, between residential and commercial sectors. The residential ZEV survey was a specialized component of the 2024 CVS, focusing specifically on households that own or lease PHEVs, BEVs, or FCEVs. This targeted survey was developed to better understand the unique experiences, preferences, and future intentions of ZEV owners.

Residential ZEV Sampling Plan

This section explains the sampling plan for residential ZEV owner sample. Recruitment methodology, data retrieval, and incentives were the same as those implemented for the main residential sample.

Survey Population

The population for the residential ZEV owner vehicle survey was composed of households in California that own at least one registered plug-in or hydrogen fuel-cell vehicle, as the California Energy Commission personal LDV forecasting model operates at a household level.

Sampling Frame

The sampling frame for the ZEV residential vehicle survey came from the Energy Commission's ZEV vehicle registration database. All households with at least one registered ZEV were included in the sampling frame.

Sampling Methodology

The survey team used a stratified random sampling approach for the residential ZEV vehicle survey. Households were randomly selected by address at the regional level such that invitations to participate are proportional to the number of registered ZEV vehicles in each region in the state. These data are displayed in **Table 56**, along with the expected number of invitations for each region.

Table 56: Household ZEV Counts by Survey Region

Region	BEV	FCEV	PHEV	Total	Percentage of State	Assuming 7.5% Response Rate, Expected Number of Invitations
Los Angeles	424,335	8,534	162,561	595,430	47.6%	2,854
San Francisco	287,526	3,210	91,064	381,800	30.5%	1,830
San Diego	82,435	473	28,507	111,415	8.9%	534
Sacramento	44,711	509	18,620	63,840	5.1%	306
Central Valley	34,191	127	15,506	49,824	4.0%	239
Rest of State	32,374	103	17,206	49,683	4.0%	238
Total	905,572	12,956	333,464	1,251,992	100.0%	6,000

Source: CEC analysis of the 2023 California Department of Motor Vehicles data

Recruitment Methodology

Respondents were recruited into the residential ZEV survey in much the same way that respondents to the household survey were, including the two-stage invitation process, contacting respondents who have begun the survey, and coordinating visual elements of the invitations. This approach was successfully implemented in the 2024 CVS Pretest and resulted in a response rate of more than 7.5 percent for the residential ZEV supplemental survey.

Data Retrieval

Like the residential survey, the residential ZEV supplemental survey offered a fully web-based retrieval instrument. Survey invitations included a URL for completing the survey online and consistent passwords on initial and reminder invitations. The survey instrument, including the ZEV branch, was also provided in English and Spanish.

Sample Size

The target sample size for the residential ZEV survey was 500. As 56 responses were collected from ZEV-owning households during the pretest, the sample size target for the full administration was set at 444. Based on the 2024 CVS Pretest, the survey team expected a response rate of 7.5 percent, which required mailing roughly 6,000 invitations.

Incentives

Incentives were offered to ZEV owners who completed the full ZEV survey. The ZEV owner survey incentive plan was the same as the main survey for residential and commercial fleet respondents.

Residential ZEV Response Rates

The number of survey invitations distributed to each region was updated using the overall response rate observed in the residential survey pretest launch. The initial sampling plan, consisting of 7,000 invitations distributed proportionally to the number of household ZEVs in each county, was adjusted down to 6,000 to reflect the higher observed response rates from the pretest. **Table 57** shows invitation counts and response rates for each wave by region.

Table 57: ZEV Residential Invitations and Response Rates by Region

Region	Pretest Survey Invitations	Main Survey Invitations	Total Invitations	Responses	Response Rate
San Francisco	203	1,830	2,033	184	9.1%
Los Angeles	367	2,853	3,220	203	6.3%
San Diego	52	534	586	52	8.9%
Sacramento	34	306	340	29	8.5%
Central Valley	22	239	261	12	4.6%
Rest of State	22	238	260	25	9.6%
Total	**700**	**6,000**	**6700**	**505**	**7.5%**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial Survey

The commercial survey component of the 2024 CVS was designed to gather data on light-duty commercial vehicle fleets in California. The survey used address-based sampling (ABS) and a two-stage recruitment process to target commercial establishments with registered light-duty vehicles (LDVs). The survey methodology aimed to collect 2,000 completed surveys.

Commercial Sampling Plan

The commercial sampling plan explains the survey population, sampling frame and methodology, as well as the sample size.

Survey Population

The target population for the commercial fleet survey was the population of business establishments that own and operate light-duty commercial vehicle fleets in California.

Sampling Frame

Based on experience from the 2019 CVS, RSG intended to recruit commercial establishments through an ABS sampling approach. In the 2016 and 2019 CVS projects, RSG worked with IHS Markit (now part of S&P Global) to obtain California vehicle registration data for light-duty commercial vehicles (under 10,000 lbs. gross vehicle weight). These statewide registration data served as the sampling frame for commercial establishments.

The S&P Global data includes establishment and vehicle information. S&P Global classifies vehicles as "personal" or "commercial" based on the registration entity. Vehicles registered to a corporation, LLC, or other business units are classified as commercial vehicles. Those registered to an individual person are classified as personal vehicles. Because vehicles are classified based on the registration entity, there is a possibility for misclassification. S&P Global is unable to identify vehicles that may be registered to a business but used primarily for personal purposes; similarly, they are unable to identify vehicles that may be registered to an individual but used primarily for commercial purposes.

Sampling Methodology

The project team used a stratified random sampling approach for the commercial vehicle survey. Fleet owners were randomly selected by address at the region level such that invitations to participate were proportional to the estimated number of light-duty commercial vehicle operators in each region in the state. These estimates were based on S&P Global's sampling frame. **Table 58** shows the expected number of invitations to commercial vehicle operators by region.

Table 58: Commercial Vehicle Operator Counts by Region

Region	Total Commercial Operators	Percentage of State	Assuming 4% Response Rate, Expected Number of Invitations
Central Valley	18,525	10.4%	8,100
Los Angeles	84,213	47.5%	20,400
Rest of State	14,451	8.1%	3,450
Sacramento	10,710	6.0%	2,600
San Diego	16,126	9.1%	3,950
San Francisco	33,367	18.8%	8,100
Total	177,392	100.0%	43,000

Source: S&P Global analysis of California DMV 2023 registration data

During the pretest, the commercial sample was also stratified by fleet size, in categories of 1 vehicle, 2 vehicles, 3–5 vehicles, 6–9 vehicles, and 10+ vehicles. The self-reported fleet size of each pretest survey respondent was compared to that business' fleet size according to S&P Global's database. It was found that S&P Global's fleet size data are only about 42 percent accurate, with similar levels of accuracy across each fleet size category. There were no clear biases such as general over- or underestimation of fleet size found.

Considering this level of inaccuracy, and to avoid introducing bias into the sample, the fleet size stratification was dropped from the full administration's commercial sampling methodology. Instead, businesses were drawn randomly within each region, and the fleet sizes of survey respondents were roughly accurate to the population proportions. As response rates for the pretest did not vary considerably across fleet size categories, RSG was confident that enough commercial survey respondents of all fleet sizes would complete the survey without such stratification.

Recruitment Methodology

Business establishments recruited through the selected address-based sampling frame were contacted to participate using the same general approach as the residential survey. RSG used a mail-out-to-web approach for the 2024 CVS and designed a postcard to send to sampled commercial establishments. The postcard contained an introduction to the project, information about the incentives offered for completing the survey, and a URL and password to access the survey online.

An invitation letter was also sent two weeks after the original postcard invitation. The letters were sealed in custom envelopes that matched the project visual aesthetic and contained a letter with a link to the survey and similar information to the postcard. RSG has found a similar two-stage process with different invitation types improves participation rates when compared to studies where an initial invitation postcard and a reminder postcard are used. This process was used in the 2024 CVS pretest and resulted in a response rate of about 4 percent. Like the residential survey recruitment materials, the Energy Commission's printing office printed, processed, and mailed all recruitment materials for pretest surveys, and the California Office of State Publishing printed, processed, and mailed all recruitment materials for the main commercial survey effort. Full designs of the commercial invitation postcard and letter can be found in "Appendix D: Recruitment Materials."

Data Retrieval

Commercial fleet respondents completed the web-based survey online, using the URL and the password included on the survey invitations.

Sample Size

The target sample size for the commercial fleet survey was 2,000 completed surveys, including valid responses from the survey pretest and the main survey. As 314 responses were collected from businesses during the pretest, the target sample size for the full administration was 1,686. Based on the observed response rate from the 2024 CVS Pretest, the team anticipated a response rate of approximately 4 percent for the commercial survey. RSG distributed invitations to about 46,600 establishments to achieve the targeted sample size of 2,029 responses. The total sample size of 2,029 responses results in a sampling margin of error of about 2.1 percent at the state level, at the 95 percent confidence level.

Incentives

Commercial fleet respondents who completed the survey were offered a larger incentive — a $40 electronic gift card for either Amazon.com or Walmart. This higher incentive amount was based on experience with similar business studies and recognized the potentially greater time commitment required from business respondents.

This incentive structure aimed at boosting response rates in the commercial sector, where participation can often be more challenging to secure.

Table 59 shows incentive selection for all commercial respondents. Four percent (4 percent) of respondents chose to decline the survey incentive.

Table 59: Commercial Survey — Incentive Distribution

Incentive Status	Count	Percentage
Selected Amazon.com	1,870	85%
Selected Walmart	250	11%
Declined Incentive	88	4%
Total	**2,208**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial Response Rates

The number of survey invitations distributed to each region was updated using the overall response rate observed in the residential survey pretest launch. The initial sampling plan, consisting of 67,000 invitations distributed proportionally to the number of commercial establishments in each county, was adjusted down to 46,600 to reflect the high observed response rates from the pretest. At the end of the data collection period, a supplemental 7,500 invitations were distributed to ensure sample targets were met. **Table 60** shows invitation counts and response rates for each wave by region.

Table 60: Commercial Response Rates by Region

Region	Pretest	Main	Supplement	Total	Response	Rate
San Francisco	1,300	8,100	1,290	10,690	362	3.4%
Los Angeles	3,100	20,400	4,200	27,700	789	2.8%
San Diego	650	3,950	610	5,210	211	4.0%
Sacramento	400	2,600	410	3,410	128	3.8%
Central Valley	700	8,100	450	9,250	336	3.6%
Rest of State	550	3,450	540	4,540	203	4.5%
Total	**6,700**	**46,600**	**7,500**	**60,800**	**2,029**	**3.3%**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial ZEV Survey

The commercial ZEV survey was a specialized component of the 2024 CVS, focusing on businesses that own or operate PHEVs, BEVs, or FCEVs in their fleets. This targeted survey was essential for better understanding the unique challenges, benefits, and plans of businesses with ZEVs in their commercial fleets.

Commercial ZEV Sampling Plan

The commercial ZEV sampling plan includes discussion of augmented ZEV survey population, sampling frame and methodology, as well as the sample size.

Survey Population

The population for the ZEV commercial vehicle survey included business establishments that own and operate at least one plug-in electric or FCEV light-duty vehicle in California.

Sampling Frame

The sampling frame for the commercial ZEV survey came from CEC analysis of the same 2023 DMV database as the residential ZEV survey, using CEC's criteria to identify commercial entities.

Sampling Methodology

The project team used a stratified random sampling approach was for the ZEV commercial vehicle survey. Fleet owners were randomly selected by address at the survey region level such that invitations to participate were proportional to the estimated number of light-duty commercial vehicle operators with at least one ZEV in each region in the state. **Table 61** shows the counts for all commercial ZEVs — not commercial vehicle operators — by region. This table also shows the expected number of invitations sent out to fleet owners in each region.

There were two complications in the DMV commercial data. First, as mentioned, the DMV data count only the number of vehicles, not the fleet owners associated with those vehicles. While RSG ensured that addresses are not duplicated in the sample, it is possible that the same fleet owners could have vehicles registered at multiple addresses, so fleet owners may be duplicated among responses. Second, the DMV does not track ownership by commercial versus household, so these distinctions are imputed.

Table 61: Commercial ZEV Counts

Region	BEV	FCEV	PHEV	ZEV Total	Percentage of State	Assuming 3% Response Rate, Expected Number of Invitations
Los Angeles	51,206	670	12,567	64,443	50.5%	2525
San Francisco	29,449	212	5,911	35,572	27.9%	1394
San Diego	8,958	75	1,785	10,818	8.5%	424
Sacramento	4,774	43	1,383	6,200	4.9%	243
Central Valley	4,980	11	1,235	6,226	4.9%	244
Rest of State	3,338	7	998	4,343	3.4%	170
Total	102,705	1,018	23,879	127,602	100.0%	5000

Source: CEC staff analysis of 2023 California Department of Motor Vehicle registrations

Recruitment Methodology

Respondents were recruited into the commercial ZEV survey in much the same way that respondents to the commercial survey were, including the two-stage invitation process, contacting respondents who have begun the survey and coordinating visual elements of the invitations. This approach was successfully implemented in the 2024 CVS pretest and resulted in a response rate of more than 3 percent for the commercial ZEV supplemental survey.

Data Retrieval

Like the commercial survey, the commercial ZEV supplemental survey offered a fully web-based retrieval instrument. Survey invitations included a URL for completing the survey online, and consistent passwords on initial and reminder invitations.

Sample Size

The target sample size for the commercial ZEV survey was 200. As 62 responses were collected from ZEV-owning businesses during the pretest, the target sample size for the full administration was set at 139. Based on the 2024 CVS pretest, staff expected a response rate of 3 percent, which required mailing about 5000 survey invitations.

Incentives

Incentives were offered to commercial ZEV owners who completed the full survey, including the ZEV questionnaire. The incentive plan was generally the same as the main survey for commercial fleet respondents.

Commercial ZEV Response Rates

For the commercial ZEV survey, the target was 200 responses, with 61 collected during the pretest, leaving 139 for the full administration. Given the expected 3 percent response rate for ZEV businesses, about 6,800 invitations were mailed for this component, including 1,800 from the pretest. The project team received 179 responses, yielding a response rate of more than 2.6 percent.

Data Processing and Quality Assurance

The data validation and coding for both the RP and SP phases of the survey were conducted in real time through the survey instrument. The survey team performed this real-time validation because the 2024 CVS was conducted entirely online. Respondents were required to provide a valid answer to each question before proceeding, eliminating item nonresponse and ensuring that each survey was completed in its entirety.

Data Validation

Several mechanisms for validating survey data were built into the residential and commercial surveys:

1. Respondents reported the number of vehicles owned or leased by their households or commercial establishments during the screening section of the questionnaire. To ensure accuracy, the provided vehicle number was compared with the number of vehicles that a respondent reported later in the survey. If the totals did not match, respondents were reminded to enter the details of the same number of household vehicles reported earlier in the survey.
2. Respondents reported the details of future vehicles they intended to purchase as replacement or additional vehicles for their households or commercial establishments. When a respondent indicated that they intended to purchase multiple replacement or additional vehicles within a similar time frame, they were prompted to report which vehicle would be purchased first. This information enabled the project team to validate the information respondents provided about their next vehicle purchases.
3. Limitations were placed on the range of numbers respondents could enter when reporting numerical information throughout the survey to ensure that responses were reasonable. For example, respondents could only enter a current vehicle mileage between zero and 200,000 miles. Respondents could also only enter a vehicle purchase price up to $1,000,000.

Data Cleaning

The project team collected 4,059 residential responses and 2,208 commercial responses. The data were screened for outliers to ensure that all observations in the data analysis and model estimation represented realistic vehicle information and reasonable tradeoffs in the discrete choice experiments. Data cleaning included an examination of vehicle details (including purchase price, annual mileage, and fuel efficiency), survey response time, and self-reported commercial business types and employment titles. A total of 169 residential and 88 commercial responses were removed during the data cleaning process. Many of these responses have no reported household VMT or have a reported mpg value below 10 or above 90. This results in final datasets of 3,890 residential responses and 2,120 commercial responses. The results from these final datasets are presented in Chapter 7.

Reporting and Data Deliverables

RSG communicated closely with the CVS project team during data collection periods. Communication was designed to keep the Energy Commission apprised of data collection status and progress and occurred via phone meetings and email correspondence. RSG met with the commission agreement manager each week by telephone throughout the project. The weekly meetings were used to discuss survey progress, identify issues related to data collection and responses, and discuss future work to be completed. RSG also developed and provided the project team with a live survey tracking page so that the commission agreement manager could monitor the progress of the residential and commercial data collection efforts in real time.

The tracking page was accessible via a website address provided by RSG and included information on the number of respondents who completed, began, and were disqualified from the survey on each day of data collection. The tracking page also included average survey completion times and basic response tabulations for both surveys.

CHAPTER 7: Analysis of Data Quality and Survey Results

This chapter documents the results of residential and commercial surveys, as well as the corresponding ZEV owner surveys. The results presented here are based on a final dataset of 3,890 residential respondents and 2,120 commercial respondents.

Residential Survey

This section presents the results of the survey administration to the general residential sampling frame. A subsequent section of this chapter provides additional analysis of the residential ZEV owner sampling branch of the survey.

Residential Survey Response

The project team distributed postcards and follow-up letters to 53,950 addresses from the general household ABS sampling frame in August and November 2024. The addresses were sampled at random and proportionally to each of the six California regions' contributions to the state's household population. **Table 62** presents the distribution of ABS invitations for the residential survey general household sampling frame. The ABS administration yielded 1,828 completed surveys for the final dataset. The vast majority of respondents completed the survey in English (**Table 63**).

Table 62: Residential Survey — ABS Invitation Distribution and Response Rate, by Survey Region

Region	ABS Invitations Distributed	Completes	Response Rate (Completes)
San Francisco	9,691	434	4.5%
Los Angeles	21,674	747	3.4%
San Diego	4,081	177	4.3%
Sacramento	3,271	158	4.8%
Central Valley	5,080	155	3.1%
Rest of State	3,453	157	4.5%
Total	**47,250**	**1,828**	**3.9%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 63: Residential Survey — Completes by Language

Language	Completes	Percentage
English	3,858	99.2%
Spanish	32	0.8%

Source: 2024 California Vehicle Survey, California Energy Commission

Table 64 shows the counts of logins, disqualifications, partial completes, and total number of ABS completes for the residential survey. The total number of completes shows all respondents who completed the survey before data cleaning, as well as the final number of completes after data cleaning, as described later.

Table 64: Residential Survey — Response Summary

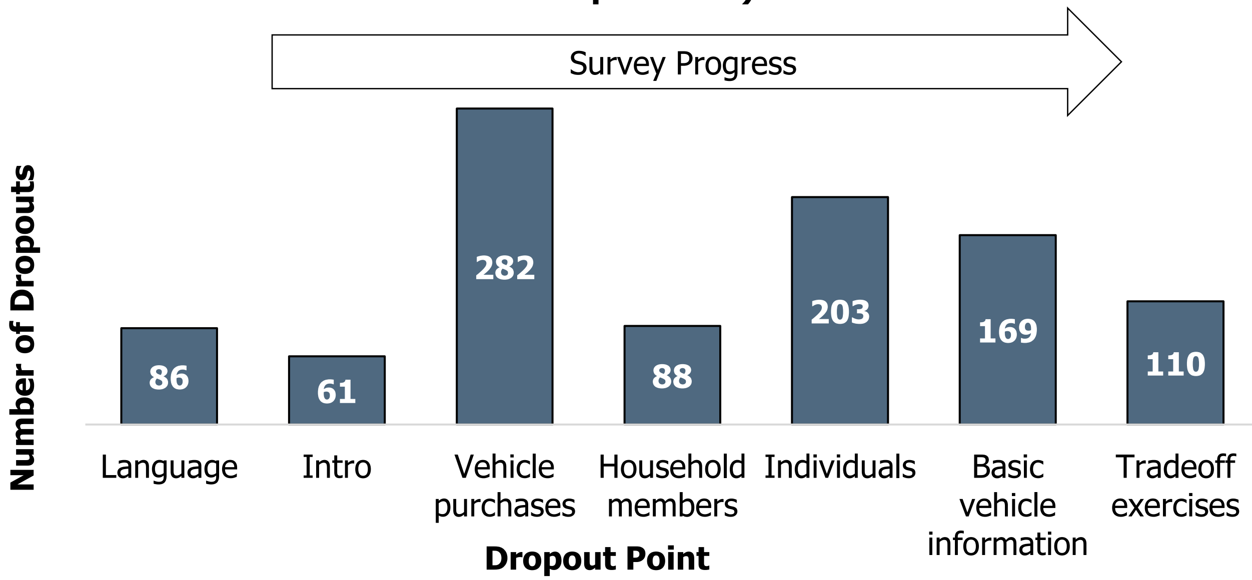
	General ABS Sampling Frame	ZEV ABS Sampling Frame	Panel Sampling Frame	Total
Invitations	47,250	6,700	N/A	53,950
Total Logins	2,434	611	2,744	5,789
Disqualifications	158	13	183	354
Partial Completes	448	93	807	1,348
Initial Completes	1,828	505	1,754	4,087
Final Completes	1,800	491	1,599	3,890

Source: 2024 California Vehicle Survey, California Energy Commission

Of the respondents who were disqualified from the survey, the most common reason was not participating in the household decision-making process when acquiring a new vehicle (36 percent of disqualified respondents), followed by not residing in California (26 percent of disqualified respondents).

Figure 12 shows the seven most common dropout locations for all residential respondents who dropped out of the survey before completing it, including respondents recruited from the ZEV sampling frame and Dynata. Respondents were most likely to drop out of the survey while reporting information about individuals in their household and while answering questions about each household vehicle. These locations were among the most detailed and demanding sections of the survey, where a higher incidence of dropouts was expected. Respondents dropped out at 59 additional locations throughout the survey, but these locations accounted for smaller fractions of overall survey dropouts.

Figure 12: Residential Survey — Dropout Locations for Partial Completes (All Respondents)



Source: 2024 California Vehicle Survey, California Energy Commission

Residential Sampling Results

Table 65 shows the results of the residential sampling effort by outreach method, as described in the previous chapter (ABS and Panel). The table shows that completed responses roughly match the targeted proportions for each of the six regions of the study. The final residential dataset collected 3,890 completed survey responses. This sample of completed surveys includes the 491 respondents recruited through the ZEV sampling frame, whose ZEV-specific survey responses are included in a separate section of this chapter.

Table 65: Residential Survey — Completes and Targeted Proportion of Completes, by Survey Region and Outreach Method

Region	General ABS Frame	ZEV ABS Sampling Frame	Panel Sampling Frame	Total Completes	Share of Completes	Targeted Share of Completes
San Francisco	425	181	321	927	24%	21%
Los Angeles	739	195	815	1,749	45%	46%
San Diego	174	51	123	348	9%	9%
Sacramento	157	27	145	329	8%	7%
Central Valley	151	12	120	283	7%	10%
Rest of State	154	25	75	254	7%	7%
Total	**1,800**	**491**	**1,599**	**3,890**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 66 through **Table 71** show the California counties that comprise each of the six study regions, with the number, percentage, and targeted percentage of completed surveys from each county.[1]

Table 66: Residential Survey — San Francisco Region Completes by County

County	Number of Completed Surveys	Percentage of Completed Surveys	Targeted Percentage of Completed Surveys
Alameda	208	20%	21.2%
Contra Costa	128	14%	14.8%
Marin	38	4%	3.7%
Napa	12	1%	1.8%
San Francisco	109	12%	13.0%
San Mateo	84	9%	9.6%
Santa Clara	255	28%	23.5%
Solano	38	4%	5.6%
Sonoma	55	6%	6.9%
Total	**927**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 67: Residential Survey — Los Angeles Survey Region Completes by County

County	Number of Completed Surveys	Percentage of Completed Surveys	Targeted Percentage of Completed Surveys
Imperial	6	0%	0.8%
Los Angeles	986	56%	54.6%
Orange	343	20%	17.3%
Riverside	195	11%	12.2%
San Bernardino	139	8%	10.7%
Ventura	80	5%	4.5%
Total	**1,749**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 68: Residential Survey — San Diego Survey Region Completes by County

County	Number of Completed Surveys	Percentage of Completed Surveys	Targeted Percentage of Completed Surveys
San Diego	348	100%	100%
Total	**348**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

1 The 27 counties comprising the "Rest of State" region are combined in Table 70 due to their small contribution to overall population and sampling targets.

Table 69: Residential Survey — Sacramento Survey Region Completes by County

County	Number of Completed Surveys	Percentage of Completed Surveys	Targeted Percentage of Completed Surveys
El Dorado	33	10%	8.1%
Placer	49	15%	16.4%
Sacramento	206	63%	60.7%
Sutter	8	2%	3.6%
Yolo	27	8%	8.2%
Yuba	6	2%	3.0%
Total	**329**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 70: Residential Survey — Central Valley Survey Region Completes by County

County	Number of Completed Surveys	Percentage of Completed Surveys	Targeted Percentage of Completed Surveys
Fresno	71	25%	24.1%
Kern	55	19%	21.0%
Kings	11	4%	3.3%
Madera	5	2%	3.3%
Merced	23	8%	6.3%
San Joaquin	49	17%	18.0%
Stanislaus	38	13%	13.3%
Tulare	31	11%	10.7%
Total	**151**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 71: Residential Survey — Rest of State Completes

County	Number of Completed Surveys	Percentage of Completed Surveys	Targeted Percentage of Completed Surveys
All Other Counties (27)	254	100%	100%
Total	**254**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Throughout this chapter, data are presented both by regions and by county types as classified by the California Association of Counties. **Table 72** shows which counties are classified as urban, suburban, and rural.

Table 72: Classification of California Counties

Urban Counties (14)	Suburban Counties (17)	Rural Counties (27)
Alameda	Butte	Alpine
Contra Costa	Imperial	Amador
Fresno	Kern	Calaveras
Los Angeles	Marin	Colusa
Orange	Merced	Del Norte
Riverside	Monterey	El Dorado
Sacramento	Napa	Glenn
San Bernadino	Placer	Humboldt
San Diego	San Luis Obispo	Inyo
San Francisco	Santa Barbara	Kings
San Joaquin	Santa Cruz	Lake
San Mateo	Shasta	Lassen
Santa Clara	Solano	Madera
Ventura	Sonoma	Mariposa
	Stanislaus	Mendocino
	Tulare	Modoc
	Yolo	Mono
		Nevada
		Plumas
		San Benito
		Sierra
		Siskiyou
		Sutter
		Tehama
		Trinity
		Tuolumne
		Yuba

Source: California Association of Counties

Table 73 shows the share of completes by county type as classified by the California Association of Counties.

Table 73: Residential Survey — Completes by County Type

County Type	Count	Percent
Rural	144	4%
Suburban	545	14%
Urban	3,201	82%
Total	**3,890**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Respondent Demographics and Summary Statistics

This section summarizes the primary demographic, household characteristics, and vehicle data from the final dataset of 3,890 residential respondents. The survey collected respondent demographics such as home ZIP Code, age, and household information.

Table 74 shows adult age categories for all residential respondents and compares this information with the 2019–2023 U.S. Census Bureau American Community Survey (ACS) 5-year Estimates.[2] The results lean older than the 2019–2023 ACS Estimates with 30 percent of all respondents being 65 or older but comprising 20 percent of the population. Almost half of respondents (49 percent) fell in the 35-to-64-year-old age category. Respondents under the age of 18 were not eligible to complete the survey.

Table 74: Residential Survey — Age Category with ACS Estimates

Age Category	Count	Percentage	ACS Percentage
18 to 34	807	21%	31%
35 to 64	1,924	49%	50%
65 or older	1,159	30%	20%
Total	**3,890**	**100%**	**100%**

Sources: 2024 California Vehicle Survey and the 2019–2023 U.S. Census Bureau American Community Survey (ACS) 5-year Estimates Table S0101

Table 75 shows household size for all residential respondents, in comparison with the 2019–2023 ACS five-year estimates. About 37 percent of respondents lived with one other person and 22 percent lived alone.

Table 75: Residential Survey — Household Size: Survey vs Census Estimates

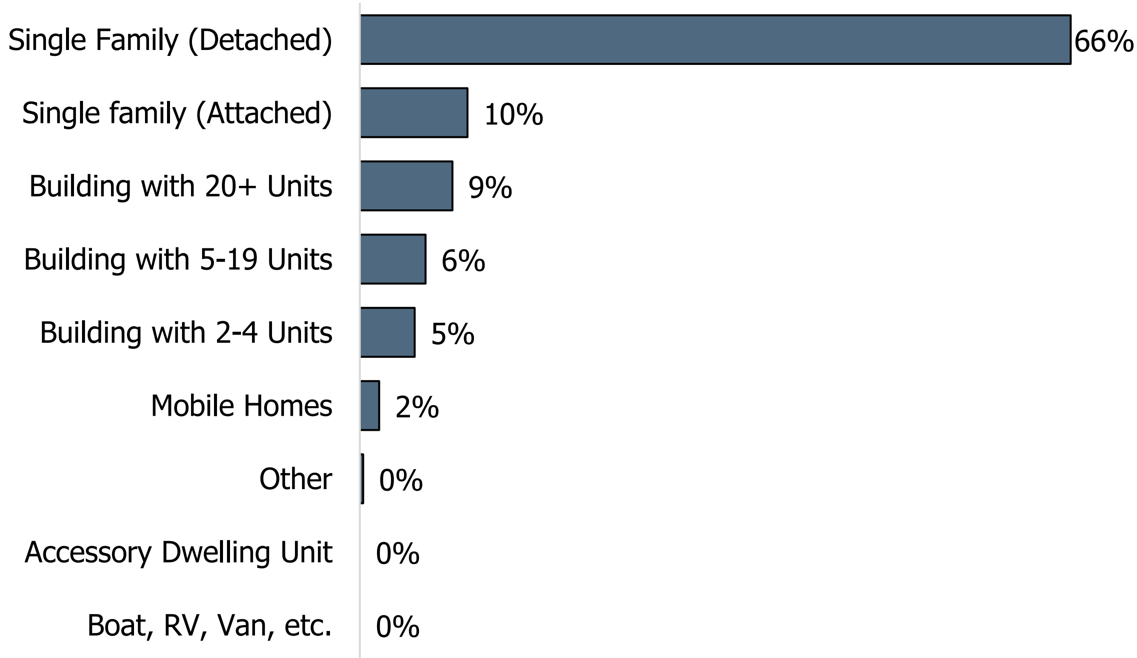
Household Size	Count	Percentage	ACS Percent
1 person	864	22%	24%
2 people	1,424	37%	31%
3 people	650	17%	17%
4 or more people	952	24%	29%
Total	**3,890**	**100%**	**100%**

Sources: 2024 California Vehicle Survey and the 2019–2023 U.S. Census Bureau American Community Survey (ACS) 5-year Estimates Table S2501

Figure 13 shows the dwelling type for all residential respondents. About two-thirds (66 percent) of respondents stated that they lived in a single-family unit that was not attached to any other housing unit.

2 U.S. Census Bureau. "2019–2023 ACS 5-Year Estimates," https://www.census.gov/programs-surveys/acs/news/data-releases/2023/release.html.

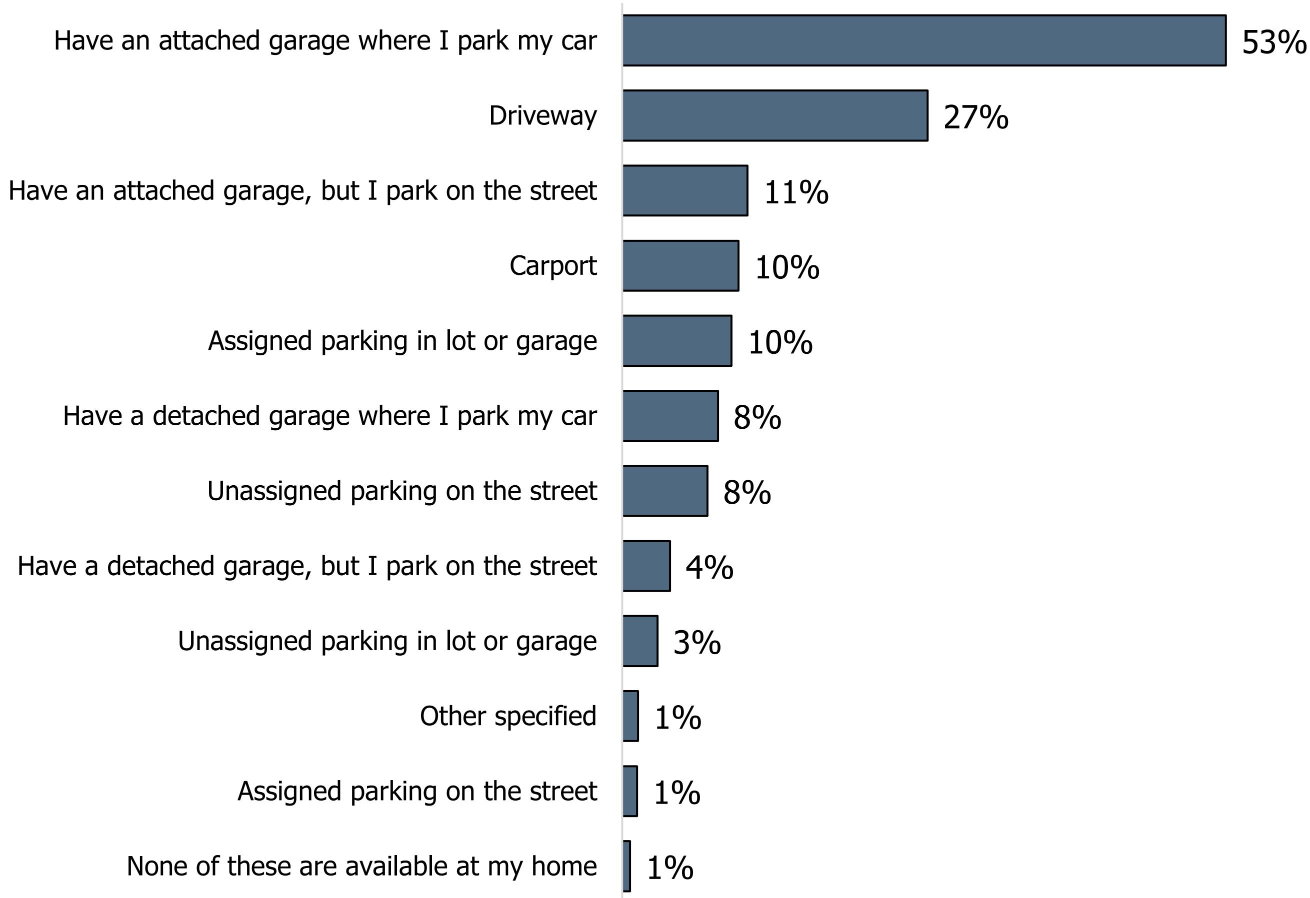
Figure 13: Residential Survey — Housing Type



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 14 shows the primary parking type for all residential respondents. More than half (53 percent) of respondents stated that they primarily park in a personal garage, while about one-quarter (27 percent) stated that they primarily park in a personal driveway.

Figure 14: Residential Survey — Parking Type



Source: 2024 California Vehicle Survey, California Energy Commission

Table 76 shows household income for all residential respondents, in comparison with the 2019–2024 ACS 5-year estimates. The median annual household income reported by respondents was in the $100,000–$149,999 range. Roughly 94 percent of respondents answered this question.

Table 76: Residential Survey — Income, With ACS Estimates

Annual Household Income	Count	Percentage	ACS Percentage
Less than $10,000	71	2.1%	4.4%
$10,000 to $24,999	158	4.3%	8.2%
$25,000 to $34,999	182	5.0%	5.5%
$35,000 to $49,999	255	7.0%	8.4%
$50,000 to $74,999	502	13.7%	13.3%
$75,000 to $99,999	453	12.4%	11.8%
$100,000 to $149,999	780	21.3%	17.9%
$150,000 to $199,999	500	13.7%	11.1%
$200,000 or more	310	20.6%	19.4%
Total	**3,660**	**100%**	**100%**

Sources: 2024 California Vehicle Survey and the 2019–2023 U.S. Census Bureau American Community Survey (ACS) 5-year Estimates Table S1901

Table 77 summarizes household vehicle ownership for residential respondents and compares this information to the 2019—2024 ACS 5-Year Estimates for households with vehicles. Although the survey and sampling frame targeted vehicle owners, 90 respondents reported owning zero household vehicles but intended to purchase or lease a vehicle in the future. Slightly less than half (42 percent) of all households reported having two vehicles, and 37 percent of households reported having one vehicle.

Table 77: Residential Survey — Household Vehicles with ACS Estimates

Household Vehicles	Count	Percentage	ACS Percentage
1 Vehicle	1,399	37%	33%
2 Vehicles	1,609	42%	39%
3 or more Vehicles	792	21%	28%
Total	**3,800**	**100%**	**100%**

Source: 2024 California Vehicle Survey and the 2019–2023 US Census Bureau American Community Survey (ACS) 5-year Estimates Table DP04

The 3,800 residential respondents with at least one vehicle reported basic information on a total of 7,353 household vehicles that they currently own or lease. **Table 78** shows vehicle type for all household vehicles. **Table 79** shows the fuel types of all reported household vehicles. Because this includes respondents that were sampled through the ZEV sampling frame, the fuel type distribution is also presented for respondents excluding those sampled through the ZEV sampling frame. Midsize cars and compact cars were the most common vehicle types, comprising a total of 21.1 percent of all current household vehicles. Most (71 percent) of current household vehicles used gasoline for fuel, with hybrid (gasoline) comprising 8 percent of all vehicle fuel types.

Table 78: Residential Survey — Current Vehicle Type

Vehicle Type	Count	Percentage	Percentage in CA Population
Subcompact Car	215	2.9%	3.9%
Compact Car	1,338	18.2%	15.1%
Midsize car	1,550	21.1%	19.1%
Large Car	248	3.4%	2.8%
Sports Car	427	5.8%	3.2%
Subcompact Crossover	285	3.9%	3.9%
Compact Crossover	793	10.8%	18.7%
Midsize Crossover/SUV	1,155	15.7%	11%
Large SUV	361	4.9%	3.4%
Small Pickup Truck	240	3.3%	5%
Full-size/large Pick-Up Truck	495	6.7%	9.2%
Small Van	164	2.2%	3%
Full-size/large Van	82	1.1%	1%
Total	**7,353**	**100%**	**100%**

Sources: 2024 California Vehicle Survey, and California Energy Commission staff analysis of Department of Motor Vehicle data

Table 79: Residential Survey — Current Vehicle Fuel Type

Fuel Type	Count	Percentage	Percentage in CA Population
Gasoline Vehicle	5,203	70.8%	83%
Battery Electric Vehicle (BEV)	937	12.7%	4.8%
Hybrid Electric Vehicle (Gasoline) (HEV)	607	8.3%	6%
Plug-in Hybrid Electric Vehicle (PHEV)	335	4.6%	1.4%
Diesel Vehicle	148	2%	1.9%
Flex Fuel Vehicle (FFV)	84	1.1%	3%
Hydrogen Fuel Cell Electric Vehicle (FCEV)	29	0.4%	0.04%
Compressed Natural Gas (CNG) Vehicle	6	0.1%	0.00003%
Total	**7,353**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission staff analysis of Department of Motor Vehicle data

For each of the vehicles they described, respondents were asked the approximate annual mileage. **Table 80** shows mean and median VMT by vehicle and by household. Respondents from less urban regions such as the Central Valley drove their vehicles the most.

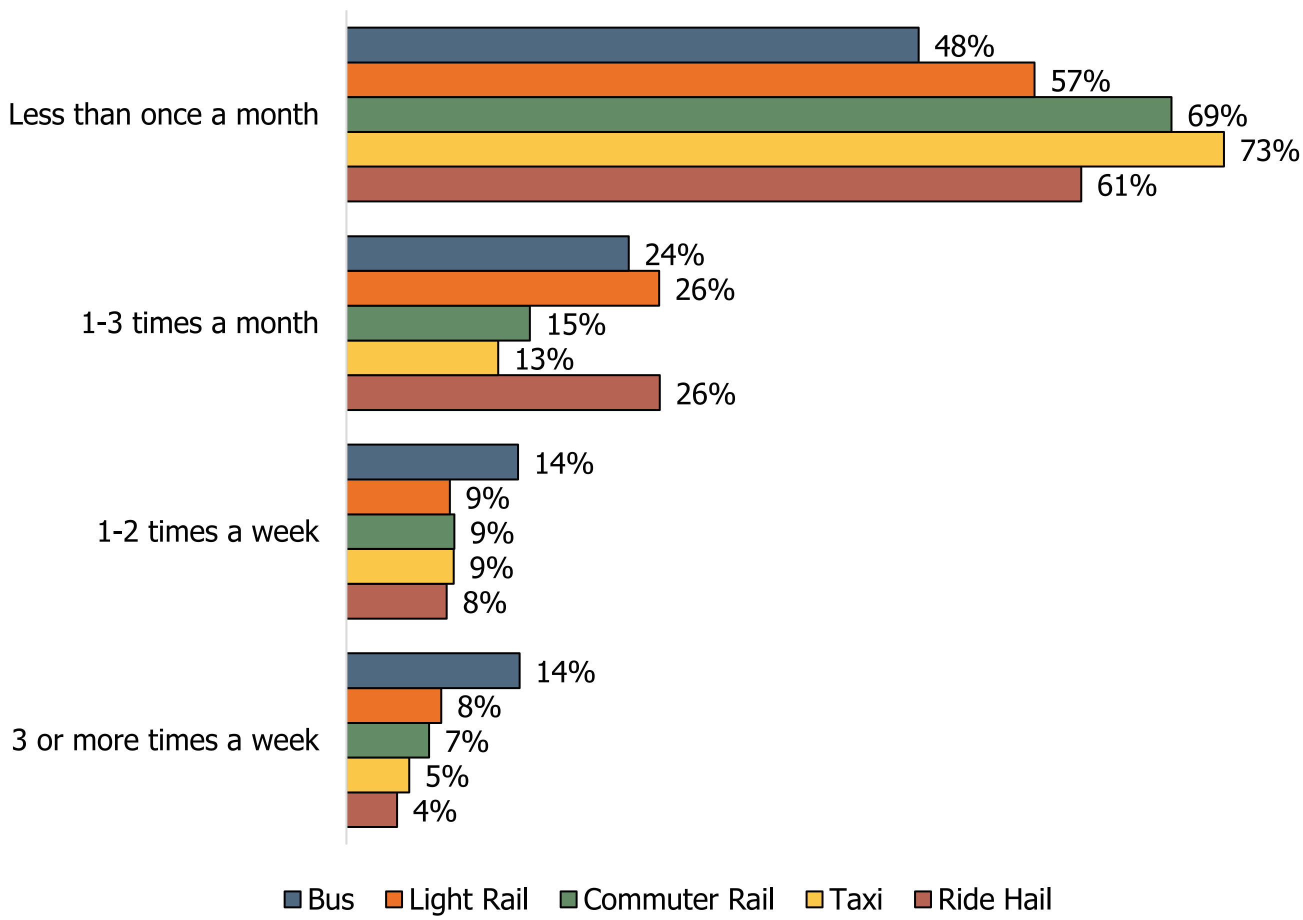
Table 80: Self-Reported VMT by Survey Region

County Type	Mean VMT Per Vehicle	Median VMT Per Vehicle	Mean Total Household VMT	Median Total Household VMT
San Francisco	9,030	7,000	17,174	12,000
Los Angeles	9,029	7,000	17,295	11,550
San Diego	8,686	7,000	16,664	12,000
Sacramento	10,176	8,000	20,129	14,400
Central Valley	11,346	8,000	21,742	14,000
Rest of State	7,927	7,000	16,616	13,000
Overall	**9,185**	**7,000**	**17,725**	**12,000**

Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were asked how often they used certain travel modes. **Figure 15** shows use-frequency of several travel modes. Note that this question was only asked for modes which the respondent reported were available for their household.

Figure 15: Travel Mode Use Frequency (When Available)

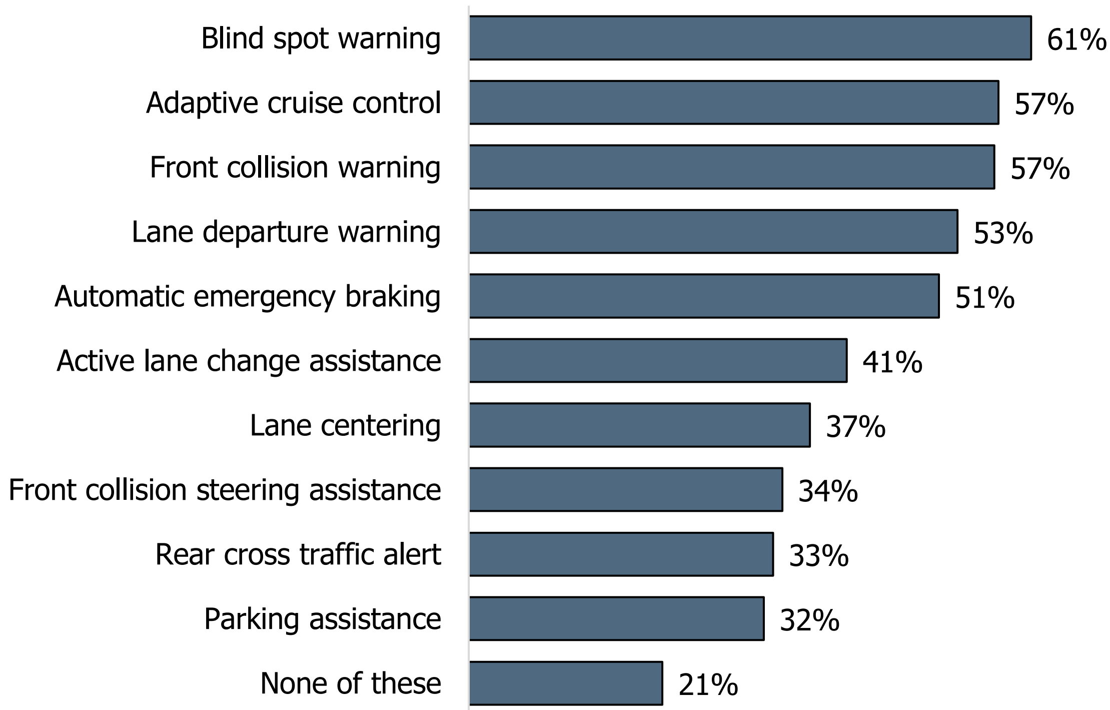


Source: 2024 California Vehicle Survey, California Energy Commission

Residential AV Attitudes

Respondents were asked if they own or had driven a vehicle with a variety of semi-autonomous features. As shown in **Figure 16**, the most common feature was blind spot warnings, and less than a quarter of respondents (21 percent) had experienced none of these features.

Figure 16: Experience Driving Vehicles with Autonomous Features



Source: 2024 California Vehicle Survey, California Energy Commission

On average, 69 percent of respondents were aware of autonomous ride-hailing services. **Figure 17** shows autonomous ride hail awareness by the survey region.

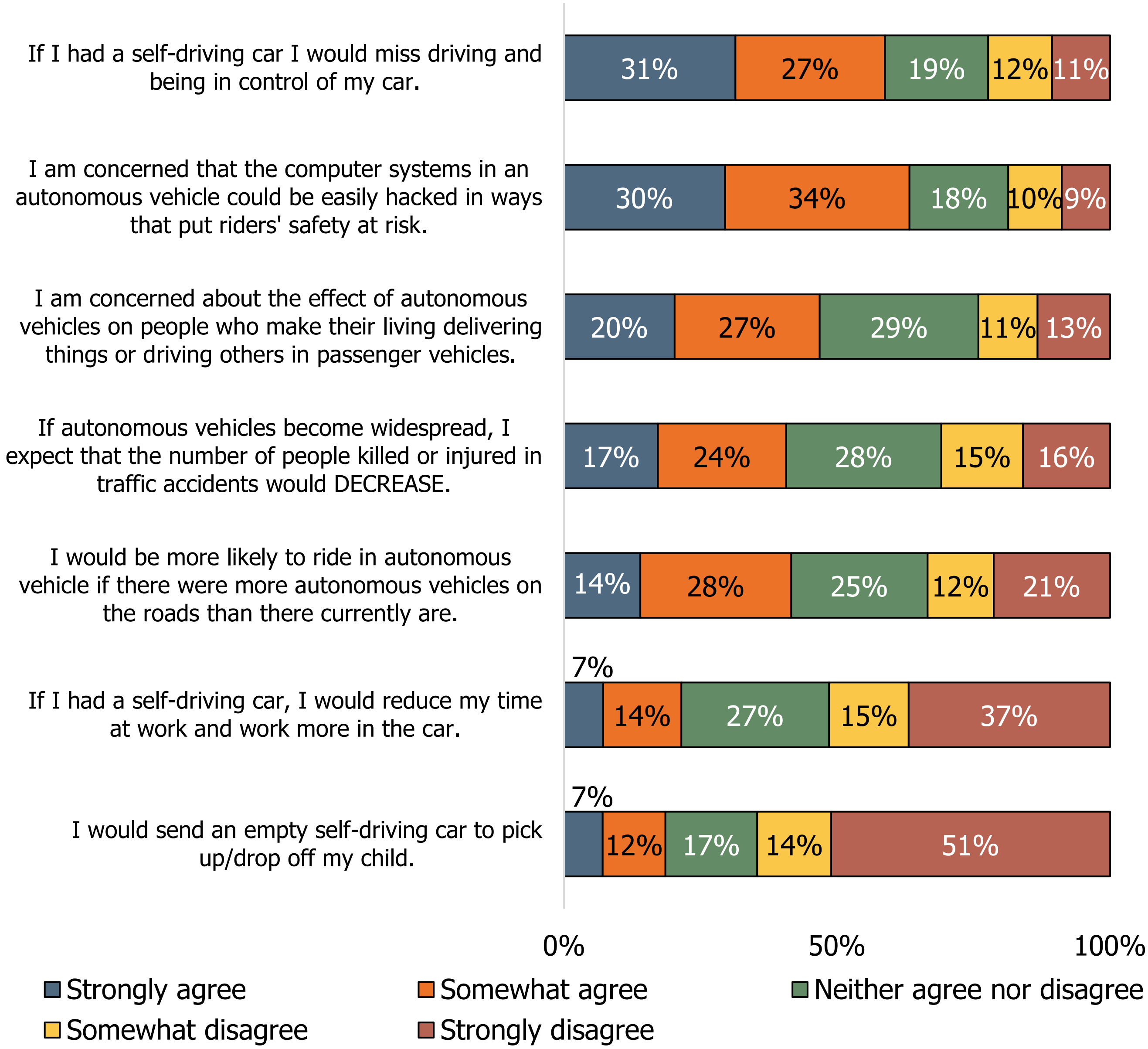
Figure 17: Awareness of Autonomous Ride-Hail by the Survey Region

Source: 2024 California Vehicle Survey, California Energy Commission

Of those respondents who were aware of autonomous ride-hailing services, only 10.1 percent had used a self-driving ride-hailing service.

Respondents were given a set of attitude statements related to autonomous vehicles and asked to rate whether they agreed or disagreed with them (**Figure 18**).

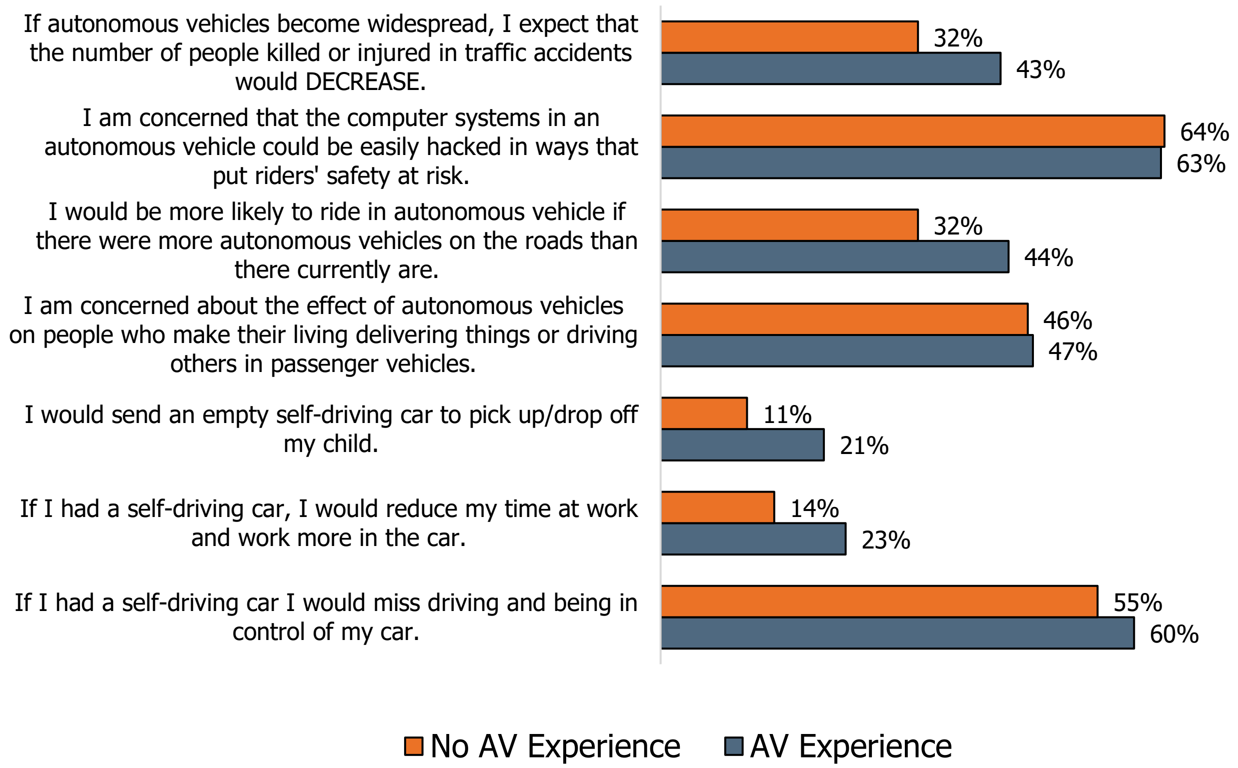
Figure 18: AV Attitudes Statements



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 19 shows the percentage of respondents who agree and strongly agree with each of the AV attitude statements, aggregated by whether or not they had ever used AV ride hailing services. Respondents with experience using AVs had more favorable attitudes about AVs.

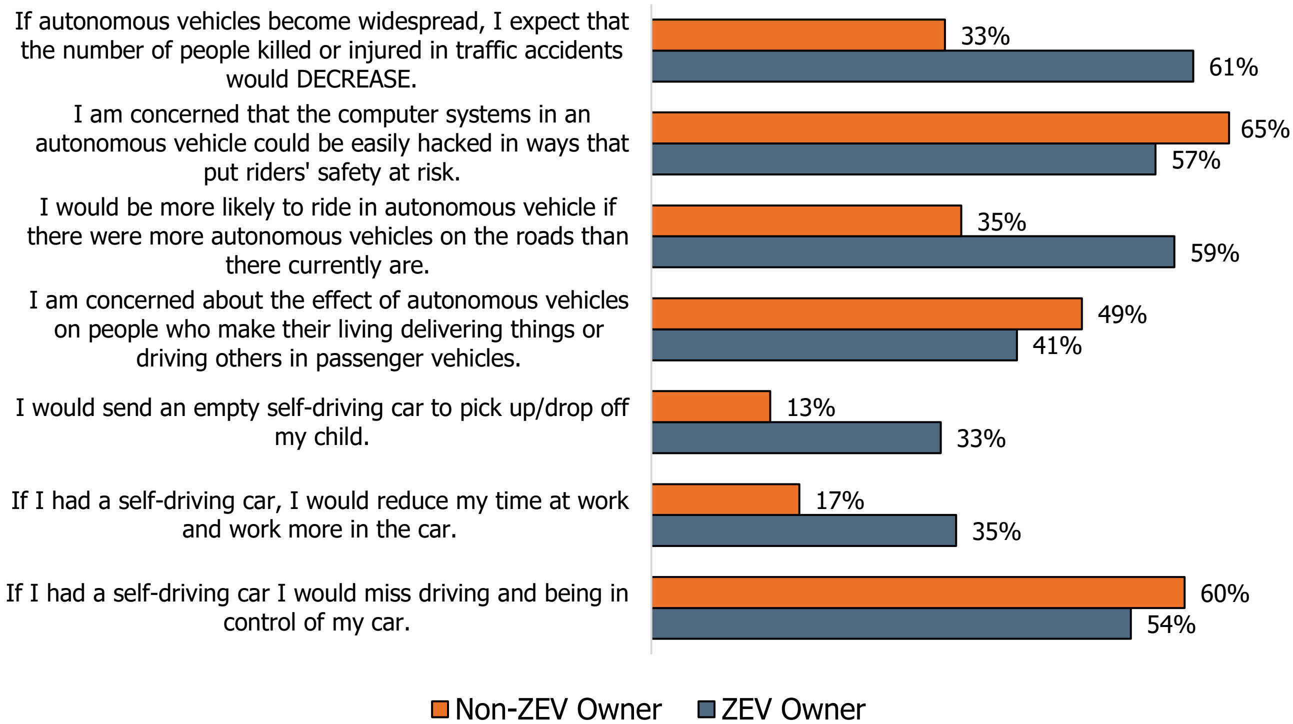
Figure 19: AV Attitudes Statements by AV Experience



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 20 is a cross-tabulation of the percentage of respondents who agree and strongly agree with each of the AV attitude statements by whether the respondent owns a ZEV. ZEV owners had much more favorable attitudes about AVs.

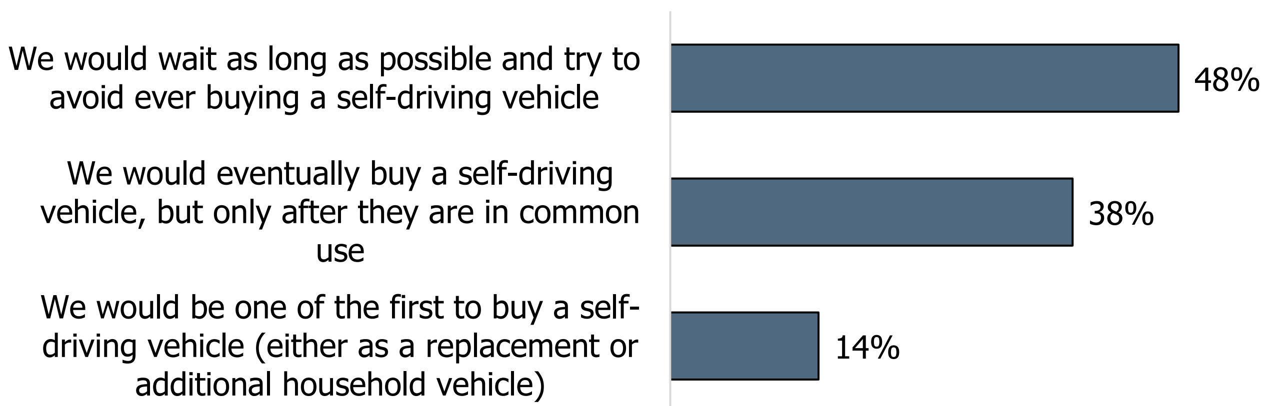
Figure 20: AV Attitudes Statement by ZEV Ownership



Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were asked how widespread self-driving vehicle availability would affect their household vehicle composition. **Figure 21** shows that just under half (48 percent) would avoid buying an AV as long as possible, while only 14 percent would be early adopters.

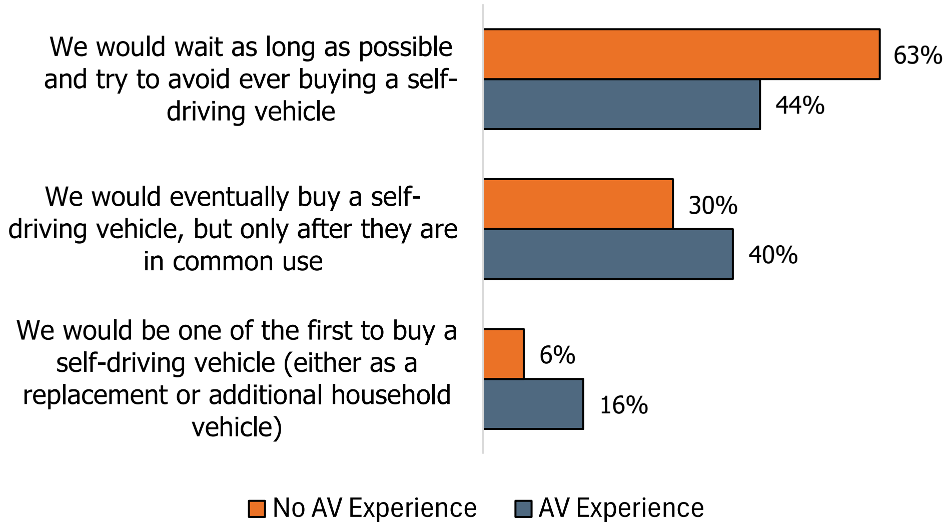
Figure 21: Anticipated Adoption of AVs



Source: 2024 California Vehicle Survey, California Energy Commission

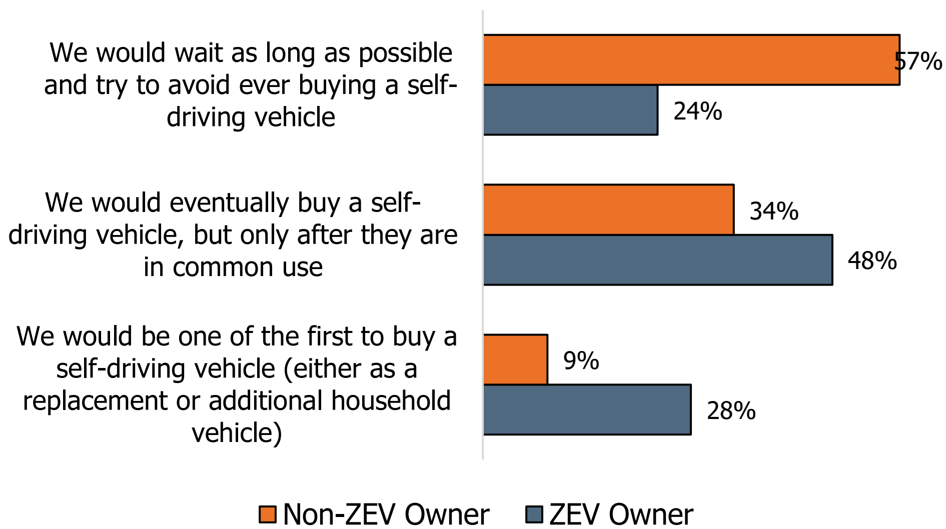
Figure 22 shows these data crossed with whether the respondent has used AV ride hailing services in the past, and **Figure 23** crosses these data with ZEV ownership. Respondents with experience using AVs were a bit more likely to say they would be early adopters of AVs, and respondents who own ZEVs were much more likely to say they would be early adopters of AVs.

Figure 22: Anticipated Adoption of AVs by AV Experience



Source: 2024 California Vehicle Survey, California Energy Commission

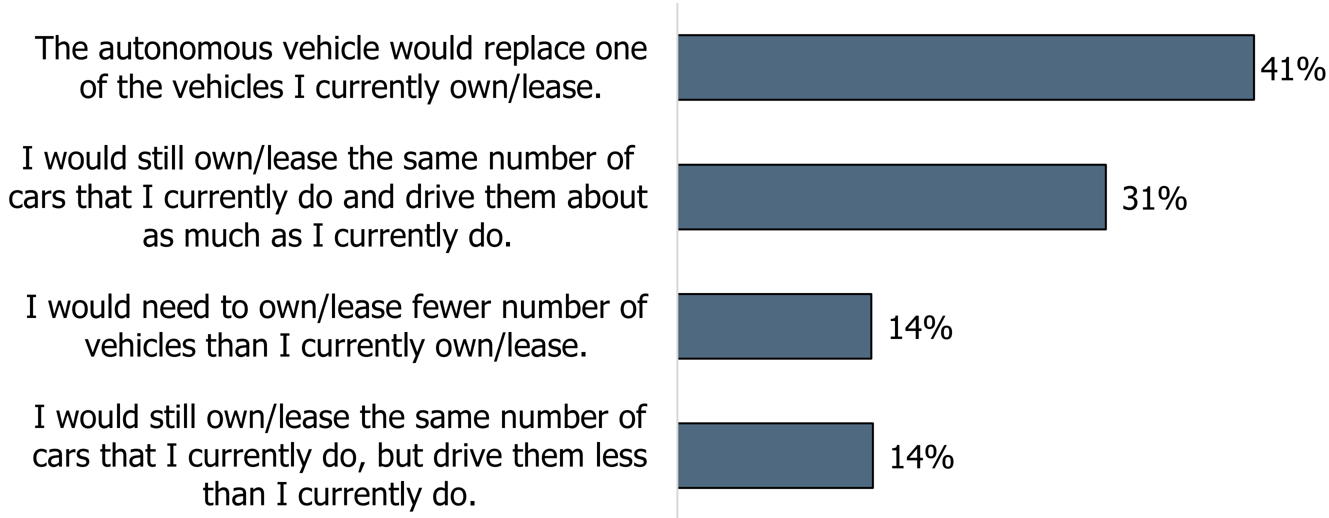
Figure 23: Anticipated Adoption of AVs by ZEV Ownership



Source: 2024 California Vehicle Survey, California Energy Commission

Respondents with at least one household vehicle were then asked how owning an AV would affect their vehicle makeup. About 41 percent of respondents would expect to replace one of their vehicles with an AV (**Figure 24**).

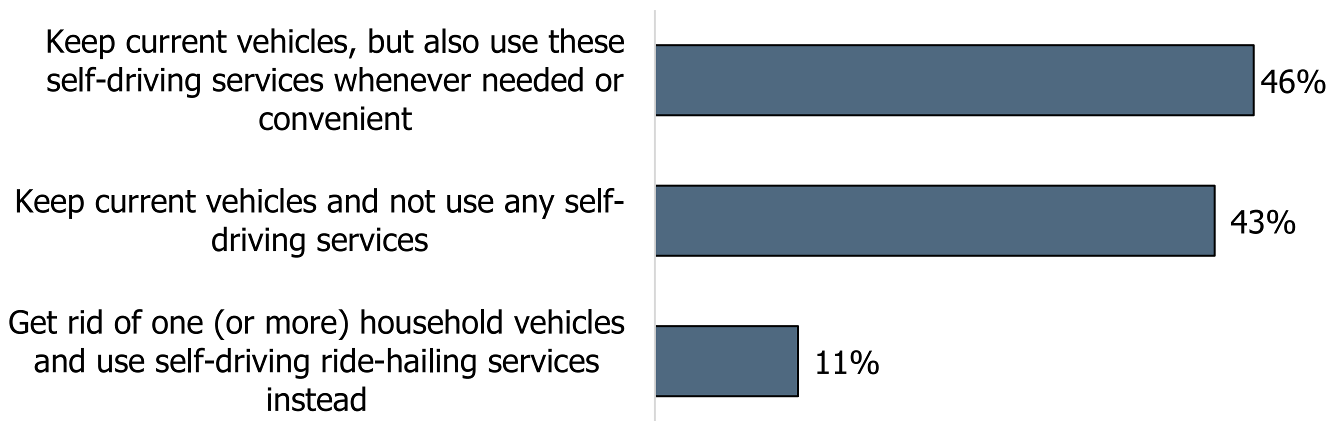
Figure 24: Anticipated Effect of Owning an AV on Household Vehicles



Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were next asked how on-demand autonomous ride-hailing services would affect their household vehicle makeup. Only 11 percent would expect to reduce the number of household vehicles in this situation (**Figure 25**).

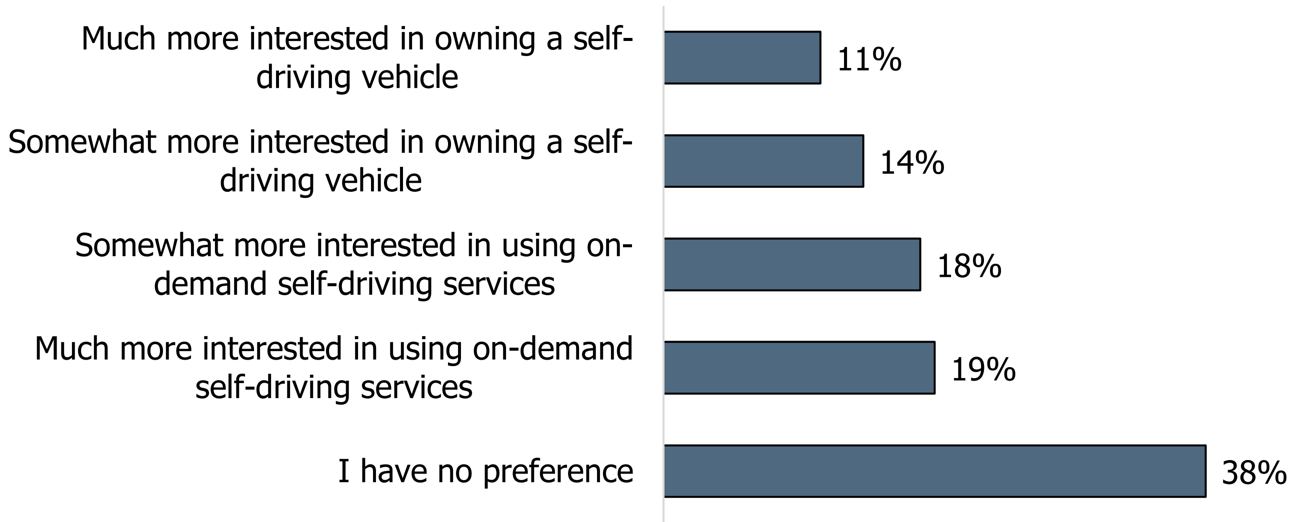
Figure 25: Anticipated Effect of Autonomous Ride-Hail on Household Vehicle



Source: 2024 California Vehicle Survey, California Energy Commission

Finally, respondents were asked about their comparative interest in owning an AV versus using autonomous ride-hail services (**Figure 26**).

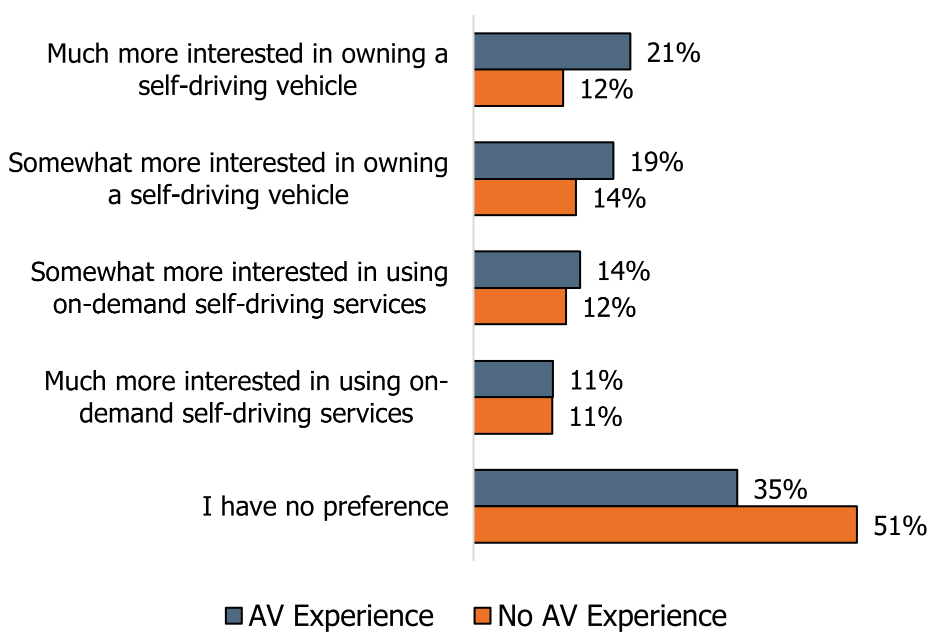
Figure 26: Interest in Owning AV Versus Using Autonomous Ride-Hail



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 27 cross tabulates these data with whether the respondent has used AV ride hailing services in the past.

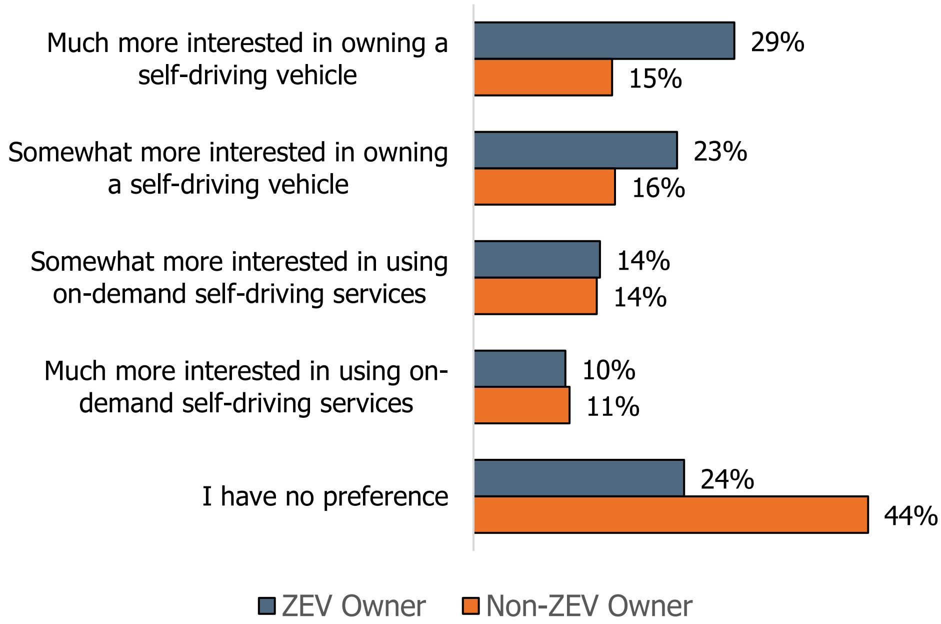
Figure 27: Interest in Owning AV Versus Using Autonomous Ride-Hail by AV Experience



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 28 cross tabulates AV data with ZEV ownership. ZEV owners are most likely to be interested in owning personal AV.

Figure 28: Interest in Owning AV Versus Using Autonomous Ride-Hail by ZEV Ownership

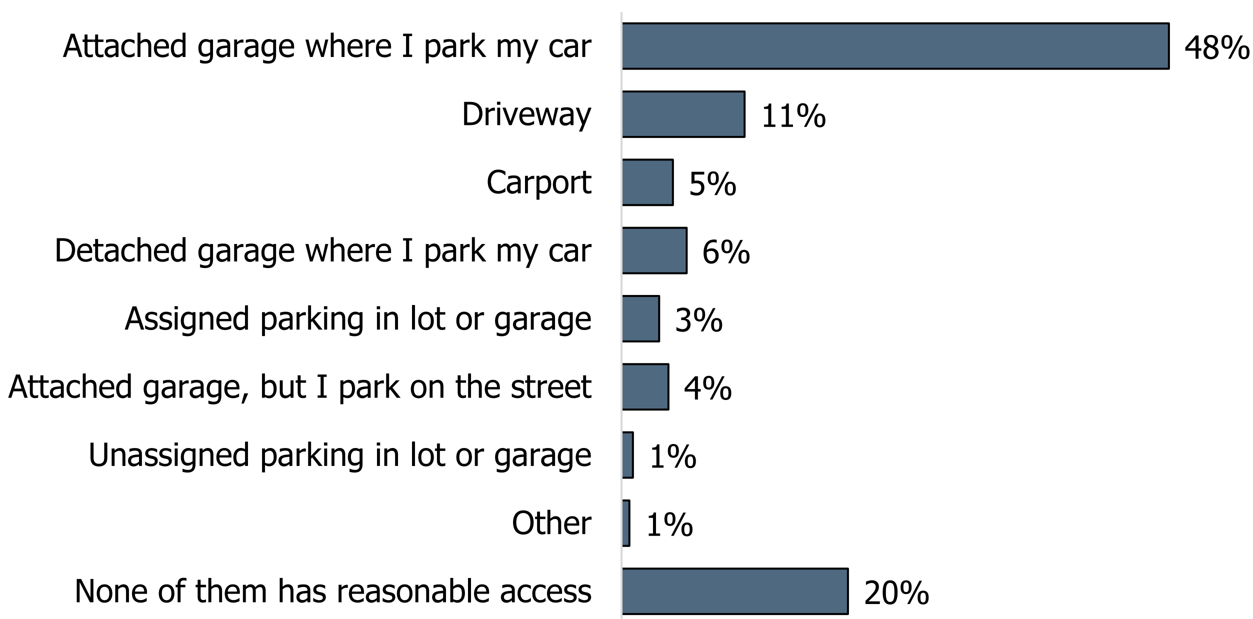


Source: 2024 California Vehicle Survey, California Energy Commission

Residential Energy Technology

When asked which of their reported parking locations would be most suitable for an EV charger, most (57 percent) respondents said an attached or detached garage (**Figure 29**). One-fifth (20 percent) said no location has reasonable access.

Figure 29: Parking Location with Best Access for Charging EV

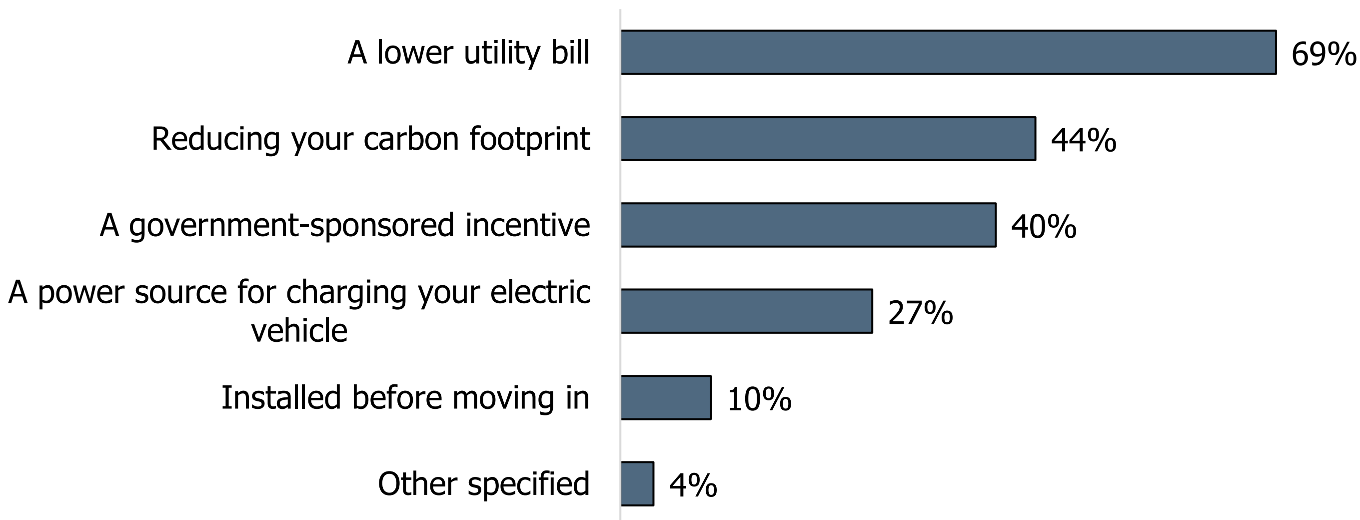


Source: 2024 California Vehicle Survey, California Energy Commission

Respondents with a BEV or PHEV were asked if they had access to a standard (120-volt) or a 240-volt outlet near where they park their vehicle. About 36.6 percent had access to a standard outlet, and 59.3 percent had access to a 240-volt outlet.

When asked if they had solar panels installed on their residence, 27 percent of respondents did. When these respondents were asked what year they installed their solar panels, the median year was 2020. **Figure 30** shows respondents' motivation for installing solar panels, with an option to include all applicable options. The most common motivation was a lower utility bill, at 69 percent. Most respondents who selected "Other" specified that they purchased a home with solar panels already installed.

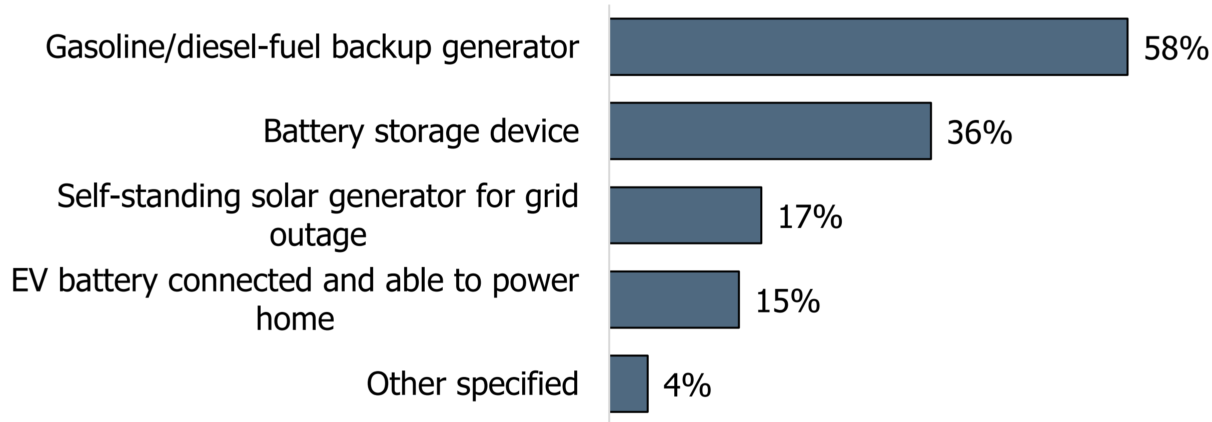
Figure 30: Motivation for Installing Solar Panels



Source: 2024 California Vehicle Survey, California Energy Commission

When asked if they had a backup energy source in case of a grid outage, 22 percent of respondents stated they did. Respondents without backup power were asked if they plan to install a source within the next five years, and 23 percent did. **Figure 31** shows the type of backup energy source that respondents had. More than half (58 percent) had a gasoline or diesel fuel generator, while only 15 percent of respondents were able to power their home with their EV.

Figure 31: Backup Energy Source Type

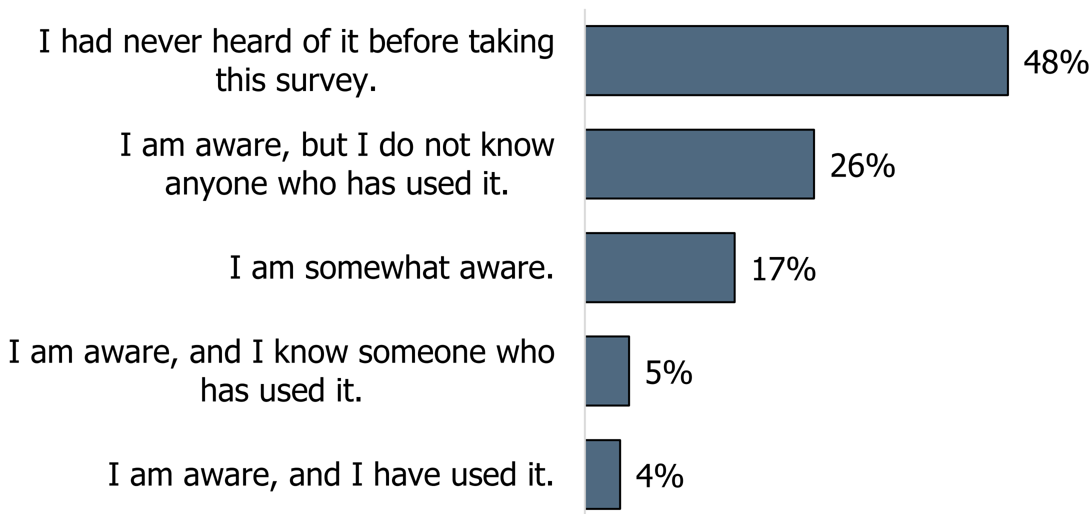


Source: 2024 California Vehicle Survey, California Energy Commission

Residential Vehicle-to-Grid Attitudes

Next, respondents were asked several questions about vehicle-to-grid technology. When asked how aware they were of the technology (**Figure 32**), almost half (48 percent) had never heard of it before, and only 4 percent had used it before.

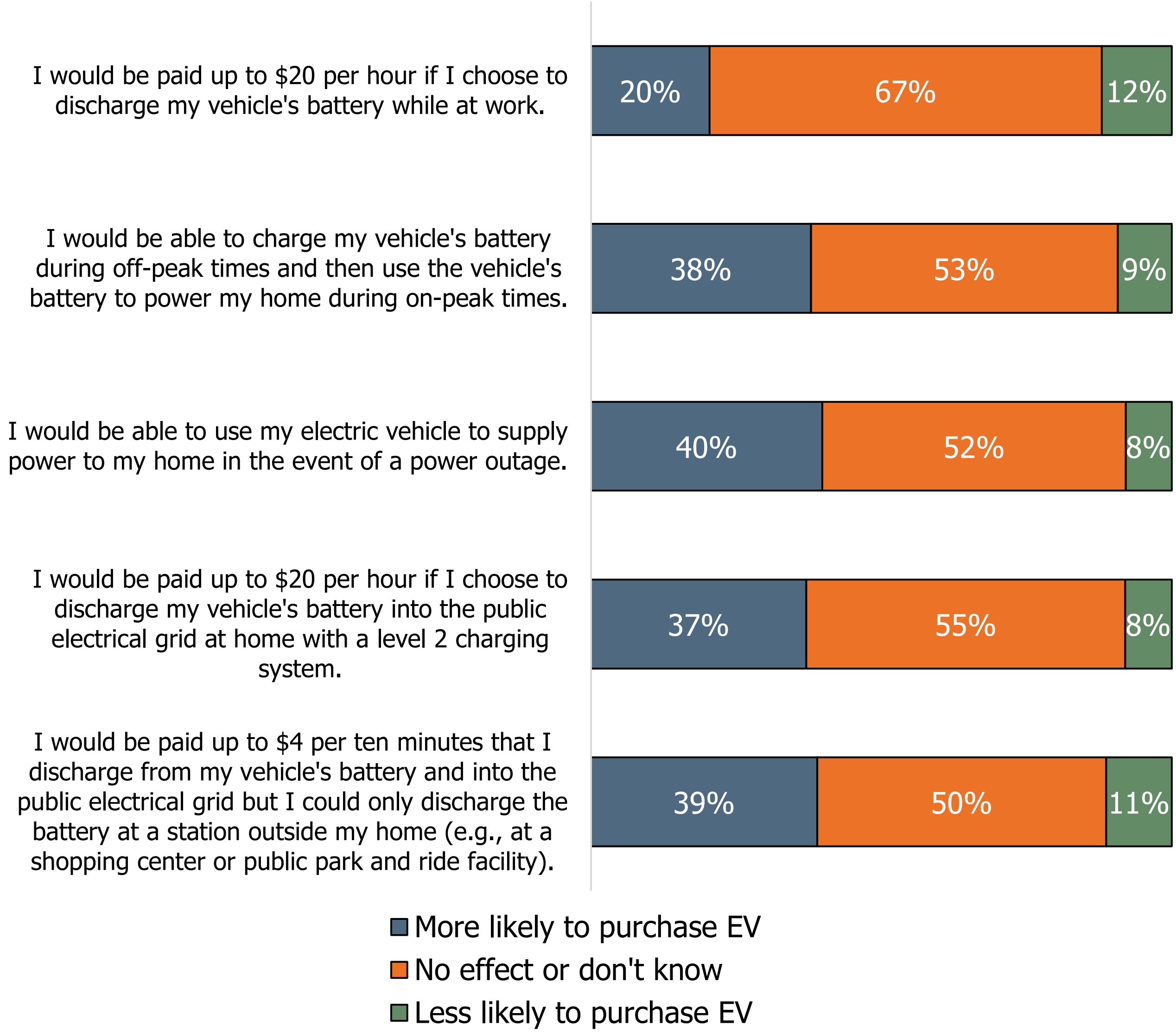
Figure 32: Awareness of Vehicle-to-Grid Technology



Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were then given scenarios and asked to consider whether they would be more or less likely to purchase an EV (**Figure 33**).

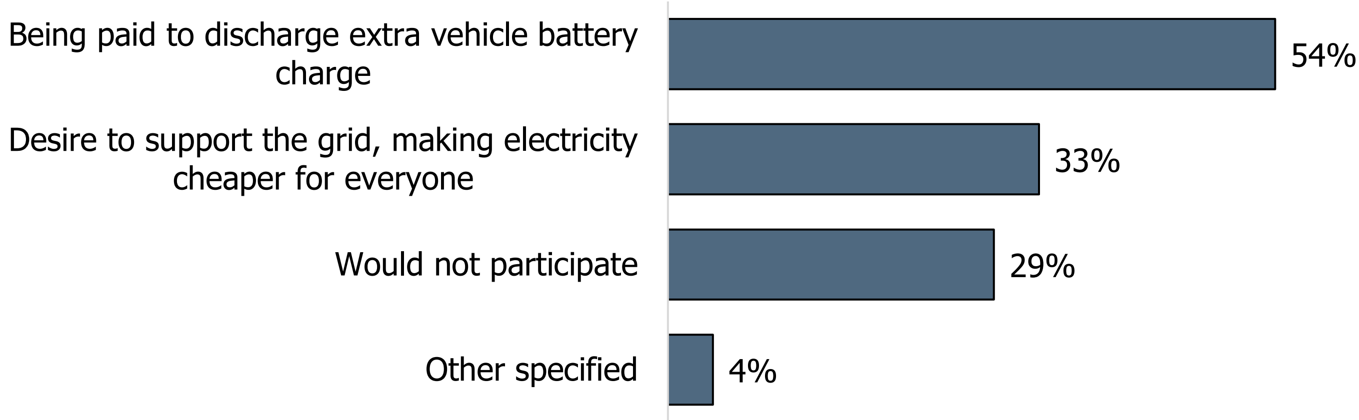
Figure 33: Effect of Vehicle-to-Grid Technology on EV Consideration



Source: 2024 California Vehicle Survey, California Energy Commission

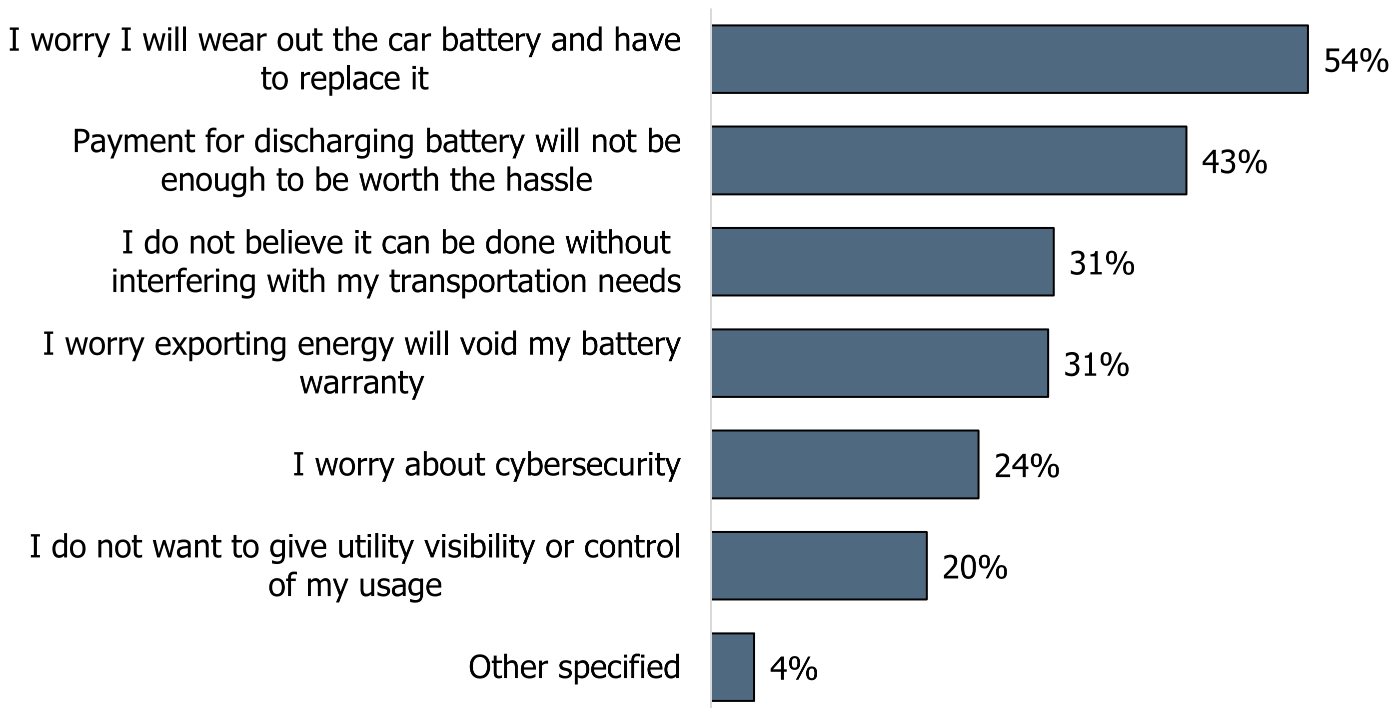
Respondents were then given factors that may increase (**Figure 34**) or decrease (**Figure 35**) their participation in vehicle-to-grid integration. Most (54 percent) would be more likely to participate if they were paid, and more than half (54 percent) would be less likely to participate due to concerns about battery wear.

Figure 34: Factors That May Increase Participation in Vehicle-to-Grid Integration



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 35: Factors That May Decrease Participation in Vehicle-to-Grid Integration



Source: 2024 California Vehicle Survey, California Energy Commission

Commercial Survey

This section documents the results of the survey administration to the general commercial sampling frame. A subsequent section of this chapter provides additional analysis for the commercial ZEV sampling frame.

Respondents were recruited into the commercial survey using a postcard distribution to a sample of businesses using address-based sampling. The survey recruitment approach is described in Chapter 6.

Commercial Survey Response

The survey team distributed postcard invitations and follow-up letters to 60,800 addresses from the general commercial ABS sampling frame obtained from S&P Global in August and November 2024. The addresses were sampled at random and proportionally to each of six California regions' contributions to the state's overall distribution of commercial vehicle fleets according to data provided by S&P Global. **Table 81** represents the distribution of ABS invitations by region for the general sampling frame of the commercial survey. The ABS outreach yielded 2,029 responses for the final commercial dataset.

Table 81: Commercial Survey — ABS Distribution and Response, by Survey Region

Survey Region	ABS Invitations Distributed	Completes	Response Rate (Completes)
San Francisco	10,690	362	3.4%
Los Angeles	27,700	789	2.8%
San Diego	5,210	211	4%
Sacramento	3,410	128	3.8%
Central Valley	9,250	336	3.6%
Rest of State	4,540	203	4.5%
Total	**60,800**	**2,029**	**3.3%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 82 shows logins, disqualifications, partial completes, and total number of postcard completes for the commercial survey. The total number of completes shows all respondents who completed the survey before data cleaning, as well as the final number of completes after data cleaning, as described in Chapter 6.

Table 82: Commercial Survey — Commercial Sampling Frame Response

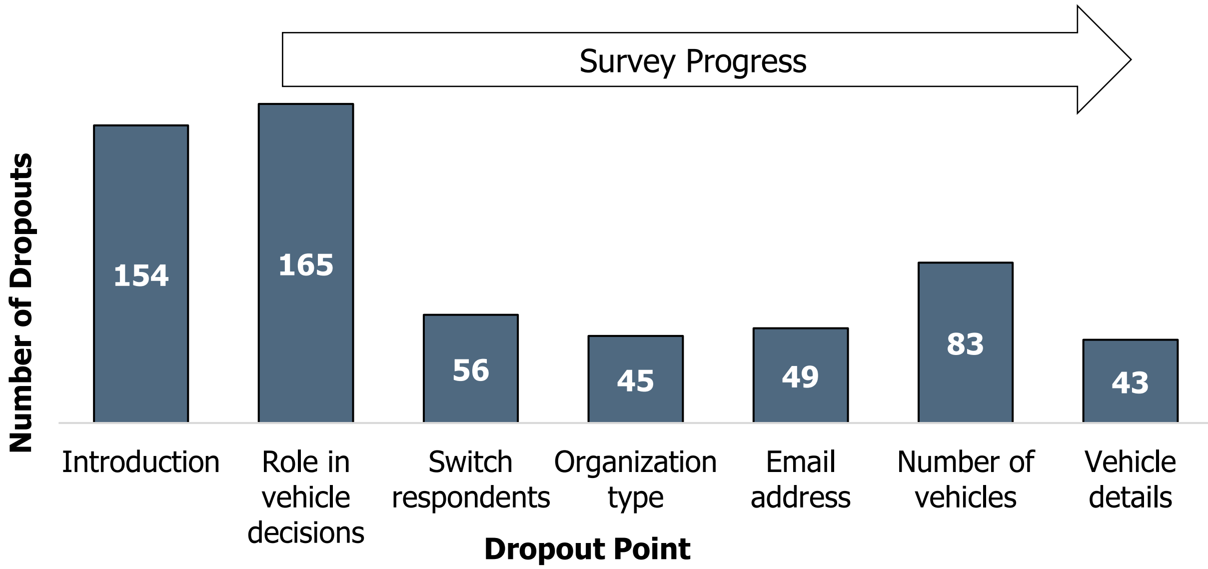
	General ABS Frame	ZEV ABS Frame	Total
Invitations	60,800	6,800	67,600
Total Logins	3,235	430	3,665
Disqualifications	443	76	519
Partial Completes	763	175	938
Initial Completes	2,029	179	2,208
Final Completes	1,958	162	2,120

Source: 2024 California Vehicle Survey, California Energy Commission

The most common reason for disqualification was working for a government agency or a car rental or taxicab company (50 percent of disqualified respondents), followed by having no light-duty vehicles registered with the respondent's company (41 percent of disqualified respondents).

Figure 36 shows the seven most common dropout locations for all commercial respondents who dropped out of the survey before completing it, including respondents recruited from the ZEV sampling frame. Respondents dropped out at 42 additional locations throughout the survey, but each of these locations accounted for only a small number of dropouts.

Figure 36: Commercial Survey — Dropout Locations for Partial Completes



Source: 2024 California Vehicle Survey, California Energy Commission

Commercial Sampling Results

Table 83 shows the results of the commercial sampling effort by recruitment method, as described in Chapter 6 (General and ZEV). The table shows that completed responses roughly match the targeted proportions for each of the six regions for the study. The final commercial dataset includes 2,120 completed survey responses. This sample of completed surveys includes the 162 respondents from the ZEV owner sampling frame, whose ZEV-specific survey responses are analyzed in a separate section of this chapter.

Table 83: Commercial Survey — Completes and Targeted Proportion of Completes, by Survey Region and Recruitment Method

Survey Region	General ABS Frame	ZEV ABS Frame	Total	Share of Completes	Targeted Share of Completes
San Francisco	346	34	380	18%	18%
Los Angeles	758	94	852	40%	44%
San Diego	206	14	220	10%	8%
Sacramento	126	4	130	6%	6%
Central Valley	326	8	334	16%	16%
Rest of State	196	8	204	10%	7%
Total	**1,958**	**162**	**2,120**	**100%**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 84 shows survey completes by fleet size and recruitment method. While most respondents managed small fleets, nearly a quarter (22 percent) had fleets of six or more vehicles.

Table 84: Commercial Survey — Completes by Fleet Size and Sample Type

Fleet Size	General ABS Frame	ZEV ABS Frame	Total	Share of Completes
1 vehicle	557	57	614	29%
2 vehicles	452	55	507	24%
3-5 vehicles	505	23	528	25%
6-9 vehicles	200	8	208	10%
10+ vehicles	244	19	263	12%
Total	**1,958**	**162**	**2,120**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 85 shows the share of completes by county type as classified by the California Association of Counties.

Table 85: Commercial Survey — Completes by County Type

County Type	Count	Percentage
Rural	99	5%
Suburban	462	22%
Urban	1,559	74%
Total	**2,120**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Respondent Demographics and Summary Statistics

This section presents key information about the 2,120 respondents in the final commercial dataset. **Table 86** shows the types of organizations where commercial respondents worked. Most (63.3 percent) commercial respondents were employed by for-profit companies.

Table 86: Commercial Survey — Organization Type

Organization Type	Count	Percentage
For-profit company	1,341	63.3%
Other/Unknown	591	27.9%
Nonprofit	188	8.9%
Total	**2,120**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial respondents were asked to report the number of locations their company operates from, in California and other U.S. states. **Table 87** shows the number of business locations in California for all commercial respondents. Seventy-nine percent (79 percent) of respondents reported working for a business or organization that operates from a single location in California.

Table 87: Commercial Survey — Business Locations in California

Business Locations in California	Count	Percentage
1 Location	1,675	79%
2 Locations	187	8.8%
3–5 Locations	150	7.1%
6–9 Locations	44	2.1%
10–19 Locations	26	1.2%
20 or more Locations	38	1.8%
Total	**2,120**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 88 shows the total number of employees based at respondents' self-reported places of work. About three-quarters (76 percent) of respondents reported working at their given addresses with fewer than 10 employees.

Table 88: Commercial Survey — Number of Employees

Number of Employees	Count	Percentage
Fewer than 10	1,220	57.5%
10–99	793	37.4%
100–999	96	4.5%
1,000 or more	11	0.5%
Total	**2,120**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

The 2,120 commercial respondents reported basic information on 13,179 vehicles that their commercial establishments owned or leased. Commercial respondents were also asked to describe the industry most closely associated with their organization and were matched with a category in the NAICS-based on this description. The respondents were grouped into three sets of industries, as displayed in **Table 89**.

Table 89: Industry Groupings

Industry Group	Industries Included
Industry Group 1	Agriculture, Forestry, Fishing, and Hunting
	Mining, Quarrying, and Oil and Gas Extraction
	Utilities (i.e., Electric, Gas, Water)
	Construction
	Manufacturing
Industry Group 2	Wholesale Trade
	Retail Trade
	Transportation and Warehousing
Industry Group 3	Information (i.e., Communications, Information Services, Publishers, Telecommunications)
	Finance and Insurance
	Real Estate and Rental and Leasing
	Professional, Scientific, and Technical Services (i.e., Lawyers, Engineering, Marketing)
	Management of Companies and Enterprises
	Administrative and Support and Waste Management and Remediation Services
	Educational Services (i.e., Schools, Colleges, Universities)
	Health Care and Social Assistance
	Arts, Entertainment, and Recreation
	Accommodation and Food Services
	Public Administration
	Repair Service
	A/O Professional, Scientific, and Technical Services Mentions

Source: 2024 California Vehicle Survey, California Energy Commission

Table 90 shows the vehicle types, and **Table 91** shows the vehicle fuel types for all commercial vehicles by the three industry groups.

Table 90: Commercial Survey — Current Vehicle Type, by Industry Group

Vehicle Type by NAICS Group	Group 1 Count	Group 1 Percent	Group 2 Count	Group 2 Percent	Group 3 Count	Group 3 Percent	Group Other Count	Group Other Percent	Total Count	Total Percent
Car	422	9.1%	227	10.5%	791	25.7%	504	15.1%	1,944	14.8%
SUV/ Crossover	453	9.8%	1,382	64.2%	637	20.7%	384	11.5%	2,856	21.7%
Van/ Minivan	568	12.3%	263	12.2%	877	28.5%	740	22.2%	2,448	18.6%
Pickup Truck	3,178	68.8%	282	13.1%	771	25.1%	1,700	51.1%	5,931	45.0%
Total	**4,621**	**100%**	**2,154**	**100%**	**3,076**	**100%**	**3,328**	**100%**	**13,179**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 91: Commercial Survey — Fuel Type, by Industry Group

Vehicle Type by NAICS Group	Group 1 Count	Group 1 Percent	Group 2 Count	Group 2 Percent	Group 3 Count	Group 3 Percent	Group Other Count	Group Other Percent	Total Count	Total Percent
Gasoline Vehicle	3,542	76.7%	1,306	60.6%	2,350	76.4%	2,811	84.5%	10,009	75.9%
Hybrid	84	1.8%	451	20.9%	214	7.0%	166	5.0%	915	6.9%
Flex Fuel	106	2.3%	77	3.6%	100	3.3%	54	1.6%	337	2.6%
Plug-in Hybrid	24	0.5%	212	9.8%	47	1.5%	23	0.7%	306	2.3%
Diesel	780	16.9%	59	2.7%	98	3.2%	164	4.9%	1,101	8.4%
Battery Electric	77	1.7%	43	2.0%	261	8.5%	93	2.8%	474	3.6%
Hydrogen Fuel Cell	0	0.0%	3	0.1%	2	0.1%	14	0.4%	19	0.1%
CNG	1	0.0%	2	0.1%	3	0.1%	1	0.0%	7	0.1%
Other	7	0.2%	1	0.0%	1	0.0%	2	0.1%	11	0.1%
Total	**4,621**	**100%**	**2,154**	**100%**	**3,076**	**100%**	**3,328**	**100%**	**13,179**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 92 shows vehicle fuel type by industry group for the commercial sampling frame, excluding the vehicles of respondents who were sampled as ZEV owners. Among vehicles owned by these respondents, 7.6 percent were ZEVs.

Table 92: Commercial Survey — Fuel Type, by Industry Group (Excluding ZEV Sampling Frame)

Fuel Type by NAICS Group	Group 1 Count	Group 1 Percent	Group 2 Count	Group 2 Percent	Group 3 Count	Group 3 Percent	Group Other Count	Group Other Percent	Total Count	Total Percent
Gasoline Vehicle	3,406	76.4%	1,261	60.9%	2,231	78.4%	2,642	85.4%	9,540	76.5%
Hybrid	83	1.9%	446	21.5%	190	6.7%	152	4.9%	871	7.0%
Flex Fuel	106	2.4%	63	3.0%	91	3.2%	54	1.7%	314	2.5%
Plug-in Hybrid	22	0.5%	210	10.1%	32	1.1%	15	0.5%	279	2.2%
Diesel	772	17.3%	55	2.7%	96	3.4%	159	5.1%	1,082	8.7%
Battery Electric	60	1.3%	33	1.6%	202	7.1%	66	2.1%	361	2.9%
Hydrogen Fuel Cell	0	0.0%	1	0.0%	1	0.0%	1	0.0%	3	0.0%
CNG	1	0.0%	2	0.1%	2	0.1%	1	0.0%	6	0.0%
Other	7	0.2%	1	0.0%	1	0.0%	2	0.1%	11	0.1%
Total	**4,457**	**100%**	**2,072**	**100%**	**2,846**	**100%**	**3,092**	**100%**	**12,467**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

For each of the vehicles they described, respondents were asked the approximate annual mileage. **Table 93** shows mean and median self-reported VMT by vehicle.

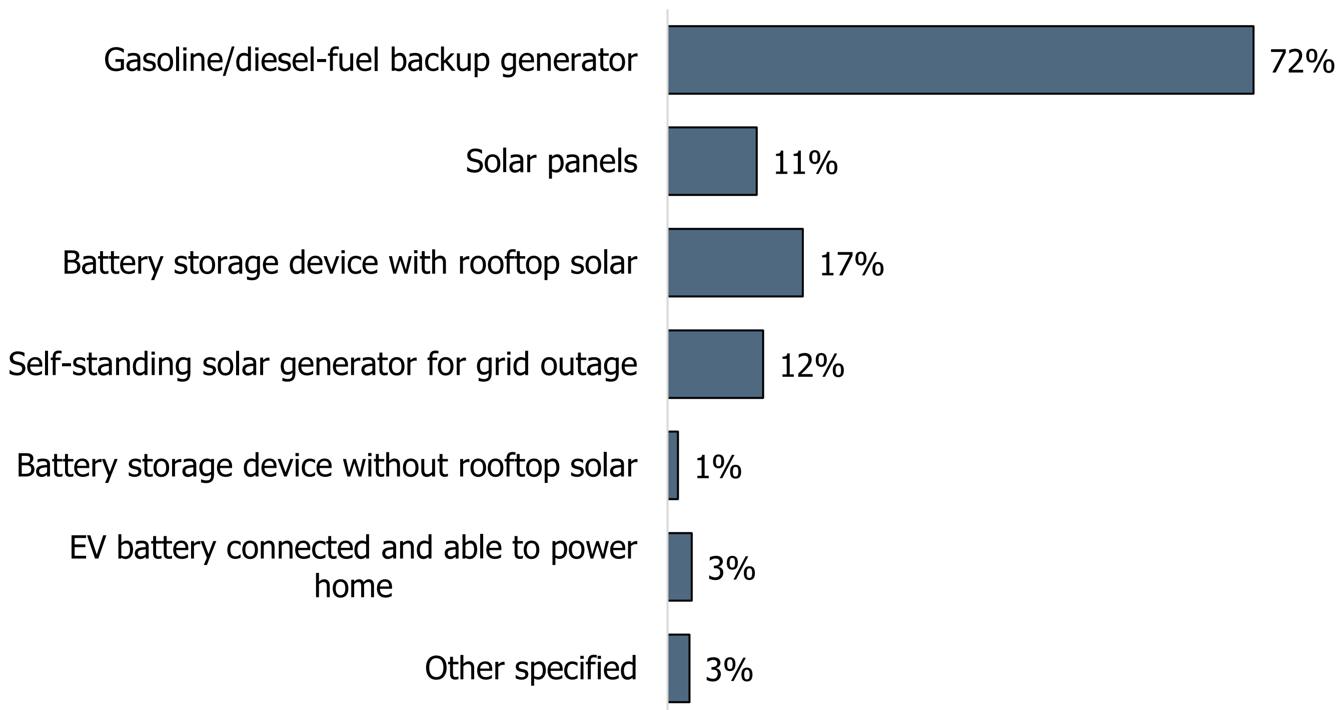
Table 93: Commercial VMT (Self-Reported) by Region

County Type	Mean VMT Per Vehicle	Median VMT Per Vehicle
San Francisco	15,403	10,000
Los Angeles	15,349	10,002
San Diego	15,241	12,000
Sacramento	17,983	12,500
Central Valley	16,542	15,000
Rest of State	15,545	12,000
Overall	**15,782**	**12,000**

Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were asked if they had a backup energy source, and 21.2 percent did. Those with backup energy sources were asked to specify what kind they had (**Figure 37**), and 72 percent had a gasoline or diesel backup generator.

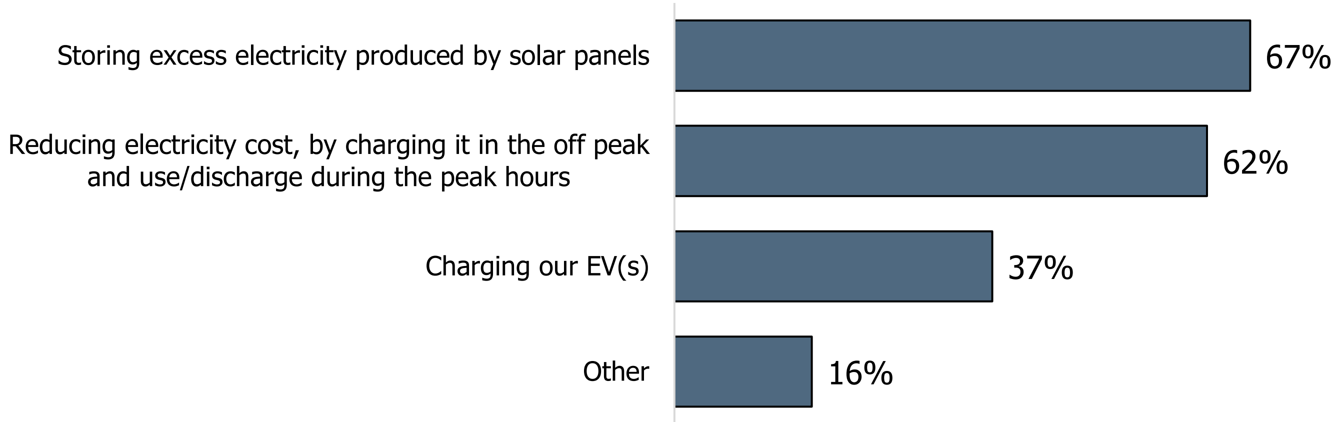
Figure 37: Backup Energy Source Type



Source: 2024 California Vehicle Survey, California Energy Commission

Respondents with backup energy sources had a median of two such devices. Respondents with battery storage devices were asked what purposes they used them for. As shown in **Figure 38**, 62 percent used it to reduce electricity cost, and two-thirds (67 percent) used it to store excess electricity produced by solar panels.

Figure 38: Battery Storage Device Purpose

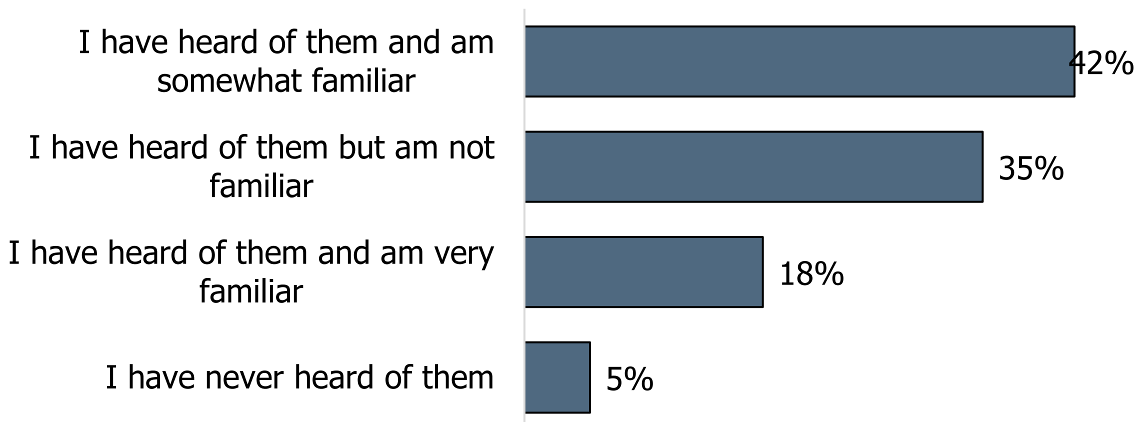


Source: 2024 California Vehicle Survey, California Energy Commission

Commercial AV Attitudes

Next, respondents were asked about their general awareness of AVs. As shown in **Figure 39**, only 4.7 percent of respondents had never heard of AVs.

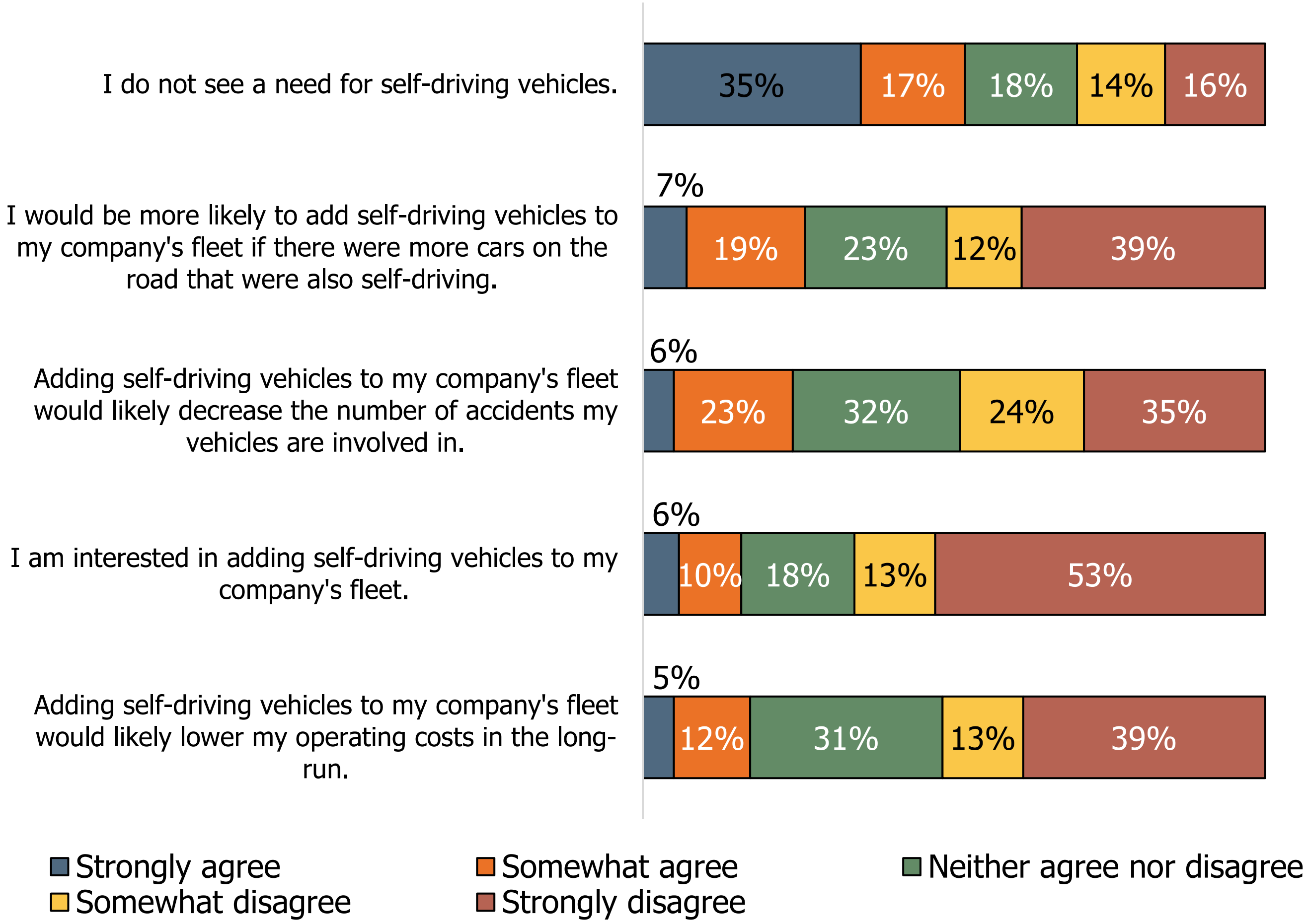
Figure 39: Awareness of AVs



Source: 2024 California Vehicle Survey, California Energy Commission

Finally, respondents were provided with several statements about AVs and asked how much they agreed with each. **Figure 40** shows respondents generally disagreed with positive statements about AVs. Nearly half (52 percent) agreed with the single negative statement: "I do not see a need for self-driving vehicles."

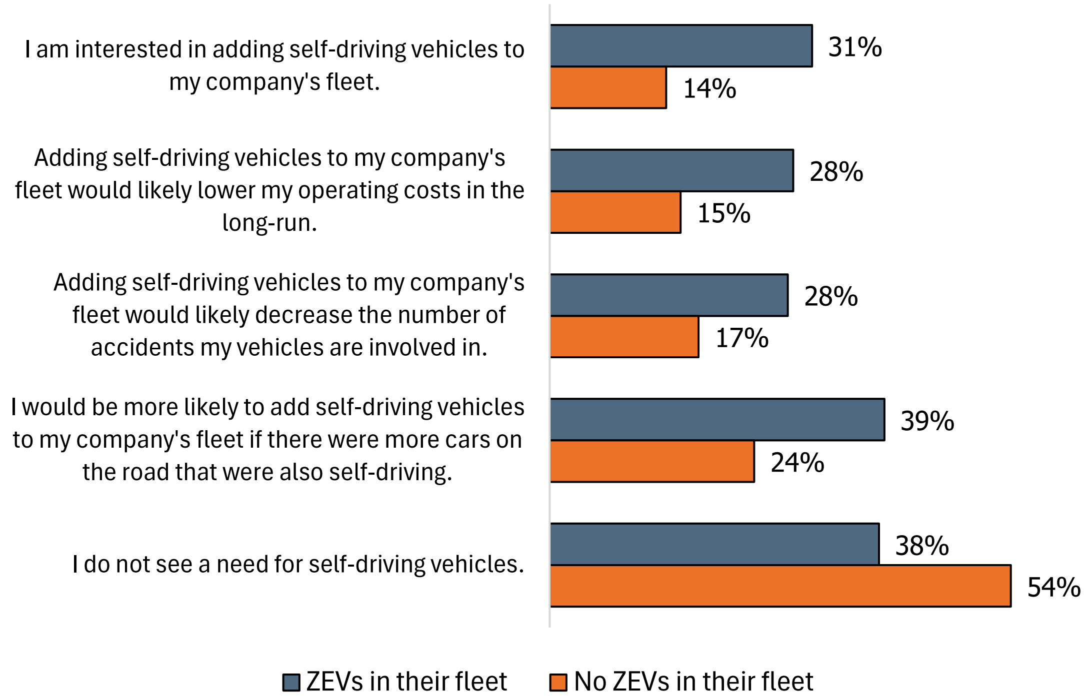
Figure 40: AV Attitude Statements



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 41 shows the same AV attitudes among commercial respondents cross tabulated with whether or not the commercial operator has ZEVs in their fleet. Operators with ZEVs were much more likely to say they are interested in adding AVs to their fleet.

Figure 41: AV Attitude Statements by ZEV Ownership



Source: 2024 California Vehicle Survey, California Energy Commission

Residential ZEV Survey

Additional ZEV questions were posed to ZEV owners in the general sample (both ABS and online panel) as well as ZEV owners in the targeted ZEV sample. This section discusses the survey data quality and survey results for the ZEV section of the residential survey.

Residential ZEV Survey Response

The project team used a separate sampling frame to recruit California residents who own or lease at least one ZEV, as documented in Chapter 6. A minimum sample size of 500 completed residential ZEV surveys was targeted. The survey population for the residential ZEV owner survey was all households in California with at least one registered light-duty ZEV — either a PHEV, a BEV, or an FCEV. For this study, the survey population excluded neighborhood electric vehicles given the significant differences in the design, use, and capabilities of these vehicles compared to standard LDVs.

RSG used an address-based sampling approach to recruit ZEV owners; this approach was like the sampling approach used for the general residential survey. The sampling frame was a complete database of all residential ZEVs registered in California as of January 2024. Respondents recruited into the general residential survey through address-based sampling, and Dynata, an online market research panel (as documented in Chapter 6), had the option to report owning a ZEV and complete the ZEV owner survey.

A stratified random sampling approach was used for the household ZEV owner survey. Households were randomly selected from the database by region such that invitations to participate were proportional to the distribution of households with registered ZEVs across the six regions of interest. **Table 94** shows the total number of ZEV owner households and number of invitations distributed to the ZEV sampling frame across the six designated California regions, along with the number of completed surveys and estimated response rate based on the number of completed surveys.

Table 94: Residential ZEV Sample — Postcard Distribution and Response, by Region

Region	ZEV Owner Households	ABS Invitations Distributed	Completes	Response Rate (Completes)
San Francisco	595,430	2,033	184	9.1%
Los Angeles	381,800	3,220	203	6.3%
San Diego	111,415	586	52	8.9%
Sacramento	63,840	340	29	8.5%
Central Valley	49,824	261	12	4.6%
Rest of State	49,683	260	25	9.6%
Total	**1,251,992**	**6,700**	**505**	**7.5%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 95 shows logins, disqualifications, partial completes, and total number of postcards completes for the ZEV sampling frame of the residential survey.

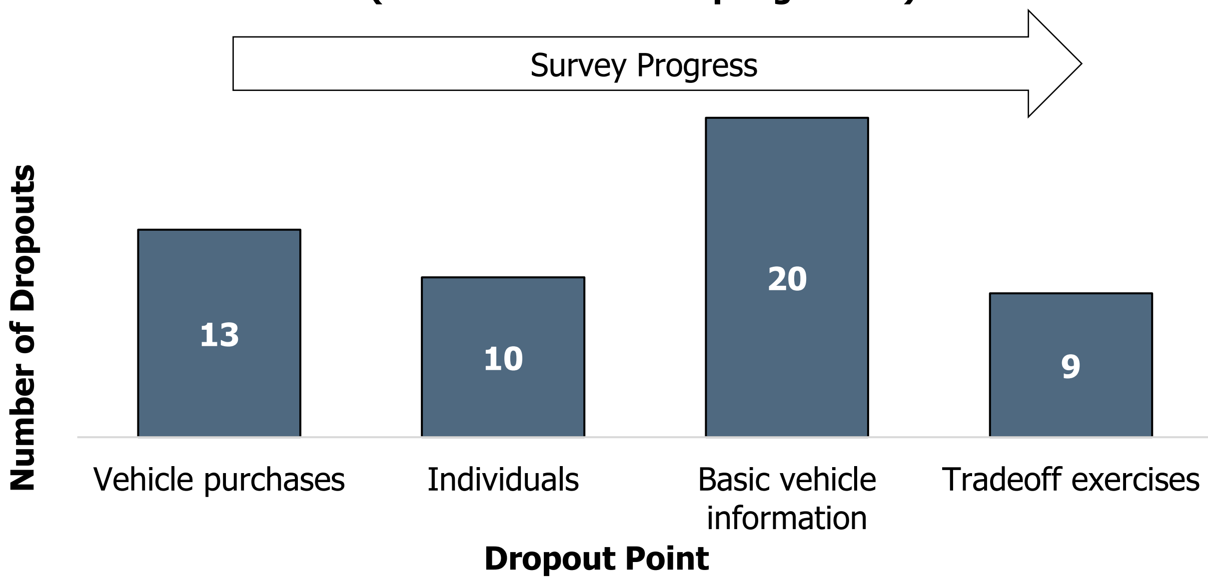
Table 95: Residential ZEV Survey — Residential ZEV Sampling Frame ABS Response

Invitations	6,700
Total Logins	611
Disqualifications	13
Partial Completes	93
Initial Completes	505
Final Completes	491

Source: 2024 California Vehicle Survey, California Energy Commission

Figure 42 shows the four most common dropout locations for all residential respondents recruited from the ZEV sampling frame who dropped out of the survey before completing it. Respondents were most likely to drop out from the survey while reporting information about individuals in their household and answering questions about each household vehicle. These locations were among the most detailed and demanding sections of the survey, where a higher incidence of dropouts was expected. Respondents from the ZEV sampling frame dropped out at 16 additional locations throughout the survey, but these locations accounted for smaller fractions of overall survey dropouts.

Figure 42: Residential ZEV Survey — Dropout Locations for Partial Completes (Residential ZEV Sampling Frame)



Source: 2024 California Vehicle Survey, California Energy Commission

While 491 respondents were recruited through the ZEV sampling frame, not all of them reported owning a ZEV. Of the 491 respondents who completed the survey through the ZEV sampling frame, 44 did not report currently owning a ZEV and were not eligible to complete the ZEV questionnaire nested within the larger residential survey. However, some respondents recruited through the general sampling frame reported owning at least one ZEV. **Table 96** shows all respondents who own a ZEV by outreach method and includes those respondents who were recruited to the ZEV survey from outside the ZEV sampling frame. The 1,031 ZEV owners reported on a total of 1,577 ZEVs that they currently owned or leased.

Table 96: Residential ZEV Survey — Completes, by Outreach Method

Outreach Method	Count	Percentage
ZEV ABS Frame	447	43%
General ABS Frame	304	29%
Research Panel	280	27%
Total	**1,031**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Summary of Residential ZEV Data

A separate questionnaire, in addition to the larger residential vehicle survey, was administered to residential respondents who owned or leased a ZEV. The questionnaire asked these respondents about the main reasons for owning a ZEV and the details about when, where, and how they charge their vehicles and the types of facilities they use for charging.

Table 97 shows the vehicle type and fuel type that respondents intended to purchase or lease for their household, either a replacement for a currently owned vehicle or an additional vehicle, for ZEV owners and non-ZEV owners. Whereas ZEV owners are much more likely to consider BEVs (36 percent vs 14 percent), non-ZEV owners are more likely to consider HEVs (29 percent vs 18 percent).

Table 97: Residential ZEV Survey — Replacement Vehicle Fuel Type by ZEV Ownership

Replacement Vehicle Fuel Type	*ZEV Owner Count*	*ZEV Owner Percent*	*Non-ZEV Owner Count*	*Non-ZEV Owner Percent*	*Total Count*	*Total Percent*
Gasoline Vehicle	371	8.6%	2,966	27.3%	3,982	26.3%
Hybrid Electric Vehicle (Gasoline) (HEV)	793	18.5%	3,189	29.3%	3,337	22.0%
Battery Electric Vehicle (BEV)	1,540	35.9%	1,489	13.7%	3,029	20.0%
Plug-in Hybrid Electric Vehicle (PHEV)	960	22.4%	1,977	18.2%	2,937	19.4%
Diesel Vehicle	101	2.4%	352	3.2%	730	4.8%
Hydrogen Fuel Cell Electric Vehicle (FCEV)	250	5.8%	451	4.2%	701	4.6%
Plug-in Hydrogen Fuel Cell Electric Vehicle (PFCEV)	279	6.5%	451	4.2%	453	3.0%
Total	**4,294**	**100%**	**10,875**	**100%**	**15,169**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 98, **Table 99**, and **Table 100** show number of household vehicles (for respondents owning at least one vehicle), household size, and annual household income for ZEV owners and non-ZEV owners. In general, ZEV owners were more likely than non-ZEV owners to own multiple vehicles, live in larger households, and have higher annual household incomes.

Table 98: Residential ZEV Survey — Number of Household Vehicles by ZEV Ownership

Household Vehicles	ZEV Owner Count	ZEV Owner Percent	Non-ZEV Owner Count	Non-ZEV Owner Percent	Total Count	Total Percent
1 Vehicle	228	16.3%	1,171	83.7%	1,399	36.0%
2 Vehicles	511	31.8%	1,098	68.2%	1,609	41.4%
3 or more Vehicles	292	36.9%	500	63.1%	792	20.4%
Total	**1,031**	**N/A**	**2,859**	**N/A**	**3,800**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 99: Residential ZEV Survey — Household Size by ZEV Ownership

Household Size	ZEV Owner Count	ZEV Owner Percent	Non-ZEV Owner Count	Non-ZEV Owner Percent	Total Count	Total Percent
1 person	123	14.2%	741	85.8%	864	22.2%
2 people	345	24.2%	1,079	75.8%	1,424	36.6%
3 people	189	29.1%	461	70.9%	650	16.7%
4 or more people	374	39.3%	578	60.7%	952	24.5%
Total	**1,031**	**N/A**	**2,859**	**N/A**	**3,890**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 100: Residential ZEV Survey — ZEV Ownership by Income

Household Size	ZEV Owner Count	ZEV Owner Percent	Non-ZEV Owner Count	Non-ZEV Owner Percent	Total Count	Total Percent
Less than $10,000	3	0.3%	74	2.8%	77	2.1%
$10,000 to $24,999	2	0.2%	156	5.8%	158	4.3%
$25,000 to $34,999	14	1.4%	168	6.3%	182	5.0%
$35,000 to $49,999	26	2.7%	229	8.5%	255	7.0%
$50,000 to $74,999	53	5.5%	449	16.7%	502	13.7%
$75,000 to $99,999	65	6.7%	388	14.5%	453	12.4%
$100,000 to $149,999	224	23.1%	556	20.7%	780	21.3%
$150,000 to $199,999	215	22.1%	285	10.6%	500	13.7%
$200,000 to $249,999	127	13.1%	183	6.8%	310	8.5%
$250,000 or more	242	24.92%	201	7.5%	443	12.1%
Total	**971**	**100%**	**2,686**	**100%**	**3,660**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

In total, 26.5 percent (n=1,031) of the final set of residential survey respondents completed the ZEV questionnaire. **Table 101** shows the count and percentage of total ZEV owner households and completed residential ZEV surveys, by region.

Table 101: Residential ZEV Survey — Completes, by Survey Region

Survey Region	Completed ZEV Surveys Count	Completed ZEV Surveys Percent
San Francisco	321	31.1%
Los Angeles	479	46.5%
San Diego	85	8.2%
Sacramento	62	6.0%
Central Valley	36	3.5%
Rest of State	48	4.7%
Total	**1,031**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Residential ZEV respondents were asked whether they had purchased home refueling equipment, upgraded their house, or used a combination of these approaches to enable them to charge their electric vehicle at home. About 49 percent of ZEV respondents indicated that they had installed home recharging equipment.

Residential Charging Behavior

Next, ZEV respondents were asked a series of questions about their vehicle charging behavior for a specific ZEV they had reported to have owned. If a respondent reported owning more than one ZEV, the respondent was asked to think about the ZEV they had first entered. If a respondent reported owning a PHEV and a BEV, they were asked to think about the BEV they owned.

Table 102 shows average charging rates per kilowatt-hour at home for all residential ZEV owners who charged their ZEVs at home and chose to report their average rate. ZEV owners who did not know their average rate had the option to skip this question without responding. On average, respondents spent 34 cents per kilowatt-hour charging their ZEVs at home.

Table 102: Residential ZEV Survey — Average Charging Cost per Kilowatt at Home

Charging Cost/Kwh	Count	Percentage
No cost	3	1.3%
Less than $0.25	76	33.0%
$0.25-$0.49	116	50.4%
$0.50-$0.74	20	8.7%
$0.75-$1.00	15	6.5%
Total	**230**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 103 shows charger type used for PHEV, BEV, and all residential PEV owners. Respondents selected all technologies that they had used to charge the batteries of their vehicles over the past month. Level 1 (standard: 25 percent of responses) and Level 2 (faster charging: 65 percent of responses) chargers were the most selected technologies. Level 1 chargers were more commonly selected by PHEV owners, while Level 2 chargers were more commonly selected by BEV owners.

Table 103: Residential ZEV Survey — Charging Technologies Used (Select All That Apply)

Charger Type	PHEV-Count	PHEV-Percentage	BEV-Count	BEV-Percentage	Total-Count	Total-Percentage
Level 1: A standard (120V) household outlet	61	27.0%	187	24.1%	248	24.8%
Level 2: A 240V outlet Free	71	31.4%	240	31.0%	311	31.1%
Level 2: A 240V outlet - Paid	74	32.7%	265	34.2%	339	33.9%
DC Fast Charger - Free	48	21.2%	149	19.2%	197	19.7%
DC Fast Charger - Paid	52	23.0%	165	21.3%	217	21.7%
Total	**226**	**N/A**	**775**	**N/A**	**1,001**	**N/A**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 104 shows vehicle charging frequency for PHEV owners, BEV owners, and all residential ZEV respondents. Respondents reported charging their vehicles along the spectrum of frequencies.

Table 104: Residential ZEV Survey — Vehicle Charging Frequency Regardless of Location

Charging Frequency	PHEV-Count	PHEV-Percentage	BEV-Count	BEV-Percentage	Total-Count	Total-Percentage
5 or more times per week	61	19.93%	90	8.95%	151	11.51%
3 or 4 times a week	96	31.37%	210	20.87%	306	23.32%
1 or 2 times a week	76	24.84%	286	28.43%	362	27.59%
Less than once a week	40	13.07%	235	23.36%	275	20.96%
Never	33	10.78%	185	18.39%	218	16.62%
Total	**306**	**100%**	**1,006**	**100%**	**1,312**	**100%**

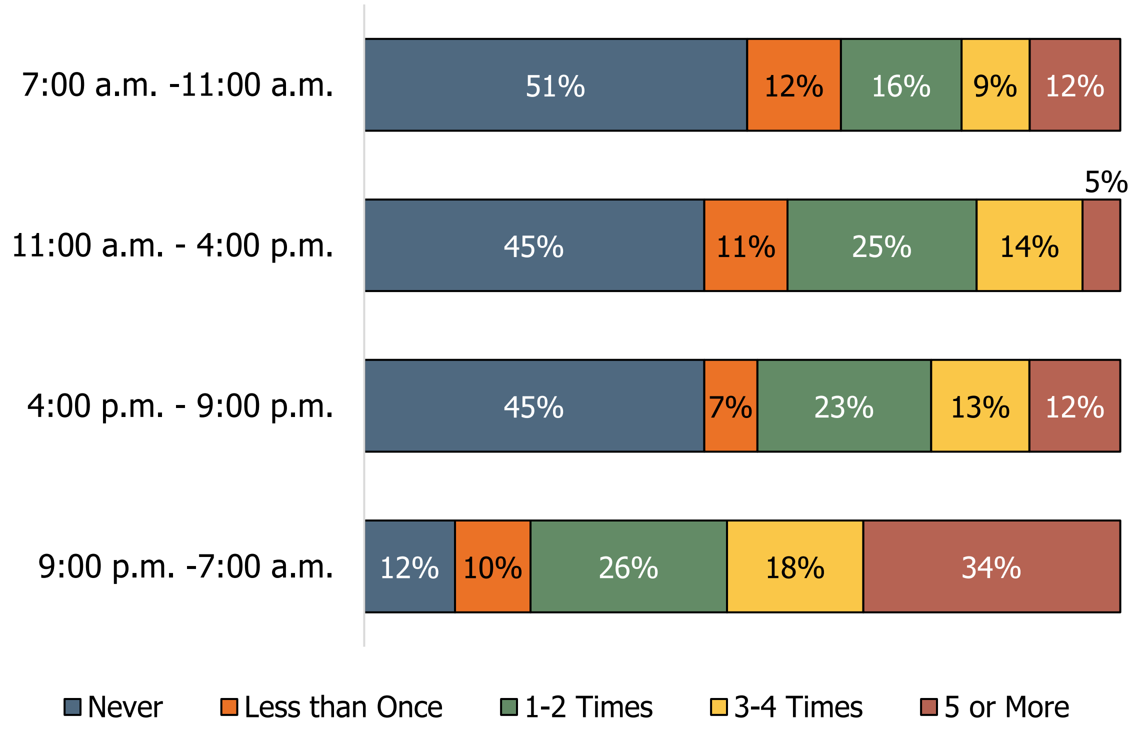
Source: 2024 California Vehicle Survey, California Energy Commission

Typical weekday and weekend charging frequencies are shown in **Figure 43** through **Figure 46** for PHEV and BEV owners.

For PHEV owners, there are clear preferences for overnight charging during weekdays, with 34.3 percent charging each of the last five days and only 12.4 percent never charging during these hours. Daytime charging is less common, with roughly half of PHEV owners never charging during morning hours (50.7 percent) and afternoon hours (45.3 percent).

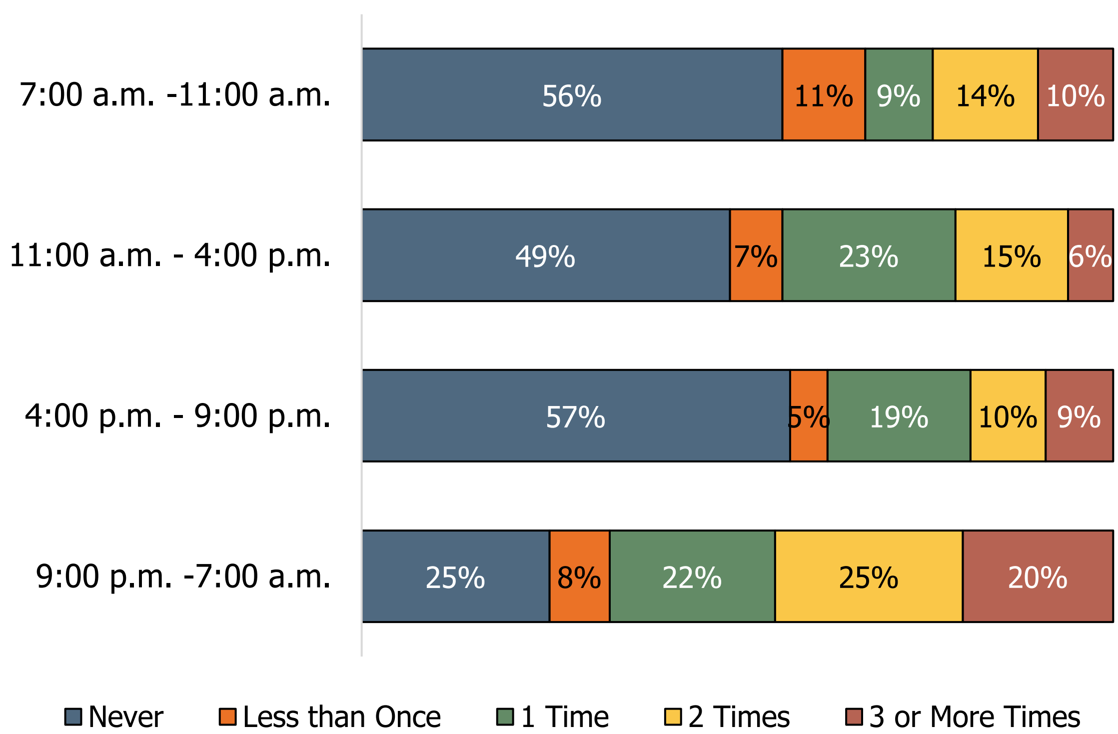
Weekend charging behavior shows a similar pattern but with generally lower frequency — overnight remains the most popular time window with 75.2 percent of owners charging at least sometimes during these hours.

Figure 43: Residential ZEV Survey — PHEV Charging Times and Frequency Weekday



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 44: Residential ZEV Survey — PHEV Charging Times and Frequency Weekend

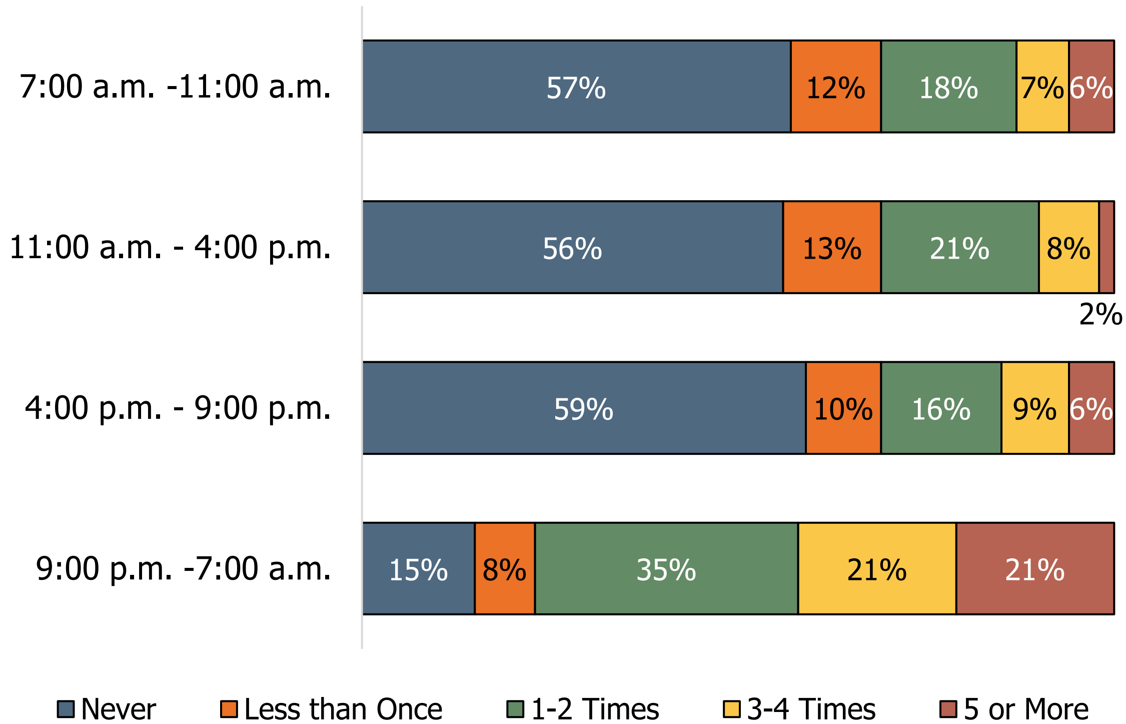


Source: 2024 California Vehicle Survey, California Energy Commission

The charging patterns for battery-electric vehicle (BEV) owners show a strong preference for overnight charging, with 77.8 percent of owners charging during nighttime hours (9 p.m.–7 a.m.) on weekdays and 74.8 percent charging during weekend nights.

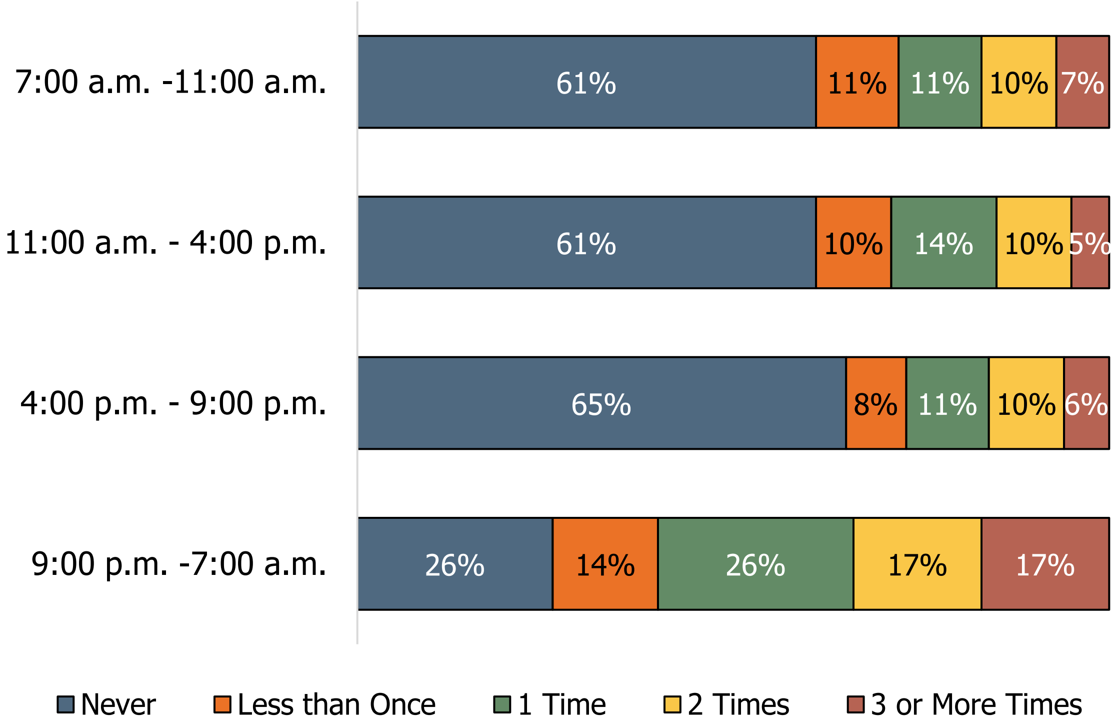
Daytime charging is significantly less common, with more than 50 percent of BEV owners never charging during morning, afternoon, or evening hours on weekdays. Weekend charging follows a similar but more pronounced pattern, with even higher percentages (58.9 percent to 62.6 percent) never charging during daytime hours.

Figure 45: Residential ZEV Survey — BEV Charging Times and Frequency Weekday



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 46: Residential ZEV Survey — BEV Charging Times and Frequency Weekend



Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were asked whether they would participate in a vehicle-to-grid program if they were paid a certain rate to do so (**Table 105**).

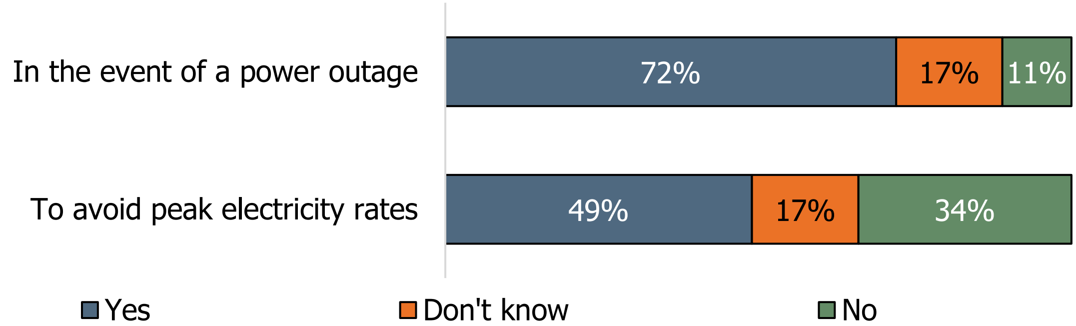
Table 105: Interest in Participating in Vehicle-to-Grid Program by Rate and Location

	$20/hour discharge at work	$20/hour discharge at home	$4/10min discharge at public station
More Likely to purchase	38.8%	37.9%	20.4%
No Effect	31.4%	32.5%	45.4%
Less Likely to purchase	11.3%	9.3%	12.0%
Don't know	18.4%	20.3%	22.2%

Source: 2024 California Vehicle Survey, California Energy Commission

Respondents were then asked whether they would be interested in discharging their vehicle battery in two scenarios. As shown in **Figure 47**, 72 percent of respondents stated they would do so if there was a power outage, while less than half (49 percent) stated they would do so to avoid peak electricity rates.

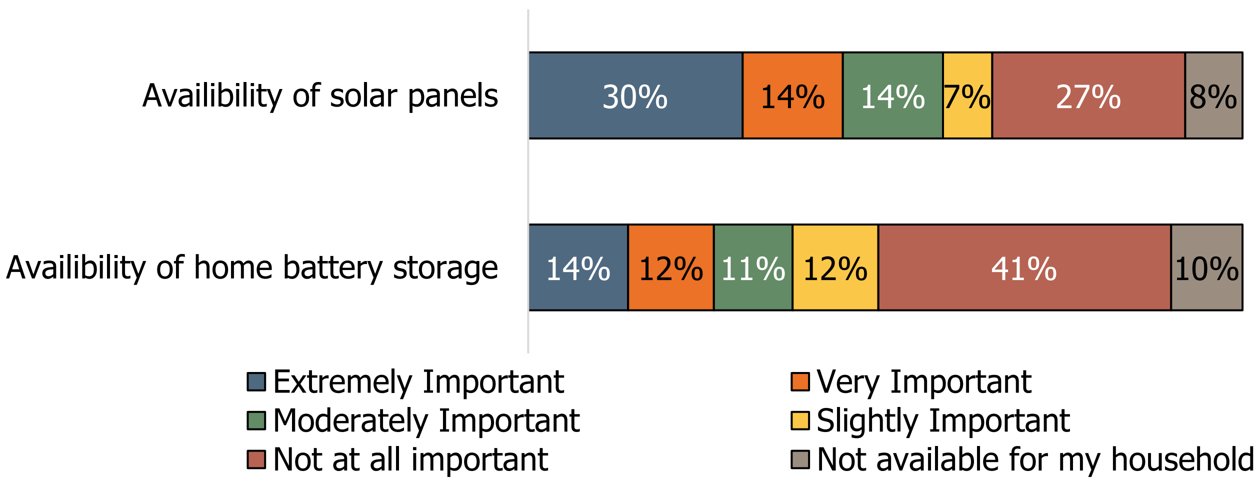
Figure 47: Interest in Discharging Vehicle Battery to Power Home



Source: 2024 California Vehicle Survey, California Energy Commission

Finally, respondents were asked how much two factors influenced their decision to purchase their EV (**Figure 48**). More than half (58 percent) said that having solar panels was at least moderately important to their decision. Almost 4 in 10 (37 percent) stated the availability of home battery storage was at least moderately important to their decision.

Figure 48: Importance of Factors in EV Decision



Source: 2024 California Vehicle Survey, California Energy Commission

Commercial ZEV Survey

This section discusses the data quality and survey results for the ZEV section of the commercial survey.

Commercial ZEV Sampling

The project team used a separate sampling frame to recruit California commercial fleet owners with at least one ZEV, as documented in Chapter 6. A minimum of 200 completed commercial ZEV surveys was targeted. The survey population for the commercial ZEV owner survey was all commercial establishments in California with at least one registered light-duty ZEV — either a PHEV, a BEV, or an FCEV.

RSG used an address-based sampling approach to recruit organizations; this approach was similar to the sampling approach used for the general commercial survey. The sampling frame was a complete database of all commercial ZEVs registered in California DMV, as of January

2024. Respondents recruited into the commercial survey through the general sampling frame also had the option to report owning a ZEV and complete the ZEV owner survey.

The project team used a stratified random sampling approach for the commercial ZEV owner survey. Commercial establishments were randomly selected from the database by region such that invitations to participate were proportional to the distribution of commercial establishments with registered ZEVs across the six regions of interest. **Table 106** shows the count and percentage of commercial ZEV invitations distributed to the ZEV sampling frame across the six designated California regions.

Table 106: Commercial ZEV Sample — Postcard Distribution and Response, by Survey Region

Survey Region	ABS Invitations Distributed	Completes	Response Rate (Completes)
San Francisco	1,875	37	2.0%
Los Angeles	3,479	107	3.1%
San Diego	573	15	2.6%
Sacramento	329	4	1.2%
Central Valley	321	8	2.5%
Rest of State	223	8	3.6%
Total	6,800	179	2.6%

Source: 2024 California Vehicle Survey, California Energy Commission

Table 107 shows logins, disqualifications, partial completes, and total number of postcard completes for the ZEV sampling frame of the commercial survey.

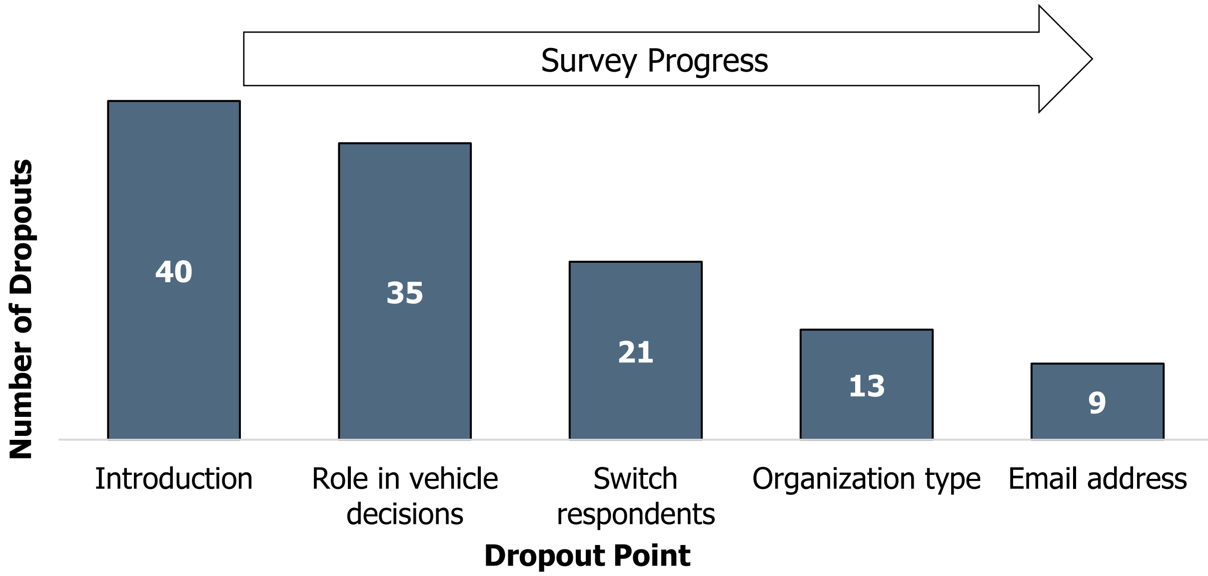
Table 107: Commercial ZEV Survey — Commercial ZEV Sampling Frame Postcard Response

Invitations	6,800
Total Logins	430
Disqualifications	76
Partial Completes	175
Initial Completes	179
Final Completes	162

Source: 2024 California Vehicle Survey, California Energy Commission

Figure 49 shows the five most common dropout locations for all commercial respondents recruited from the ZEV sampling frame who dropped out of the survey before completing it. Respondents dropped out at 20 additional locations throughout the survey, but each of these locations accounts for only a small number of dropouts.

Figure 49: Commercial ZEV Survey — Dropout Locations for Partial Completes (Commercial ZEV Sampling Frame)



Source: 2024 California Vehicle Survey, California Energy Commission

Table 108 shows all respondents who own a ZEV by outreach method and includes those respondents who were recruited to the ZEV survey from outside the ZEV sampling frame. Seventy-three respondents recruited to the survey through the ZEV sampling did not report currently owning a ZEV and were not eligible to complete the ZEV branch of the survey nested within the larger commercial survey.

Table 108: Commercial ZEV Survey — Completes, by Outreach Method

Outreach Method	Count	Percentage
ZEV ABS Sampling Frame	89	28%
General ABS Sampling Frame	231	72%
Total	**320**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Summary of Commercial ZEV Survey Data

A ZEV questionnaire was administered to commercial respondents whose establishments own or operate a ZEV in addition to the larger commercial vehicle survey. The ZEV questionnaire asked these respondents about their main reasons for owning a PHEV or BEV and the details about when, where, and how they charge their vehicles and the types of facilities they use.

Table 109 and **Table 110** shows the vehicle type and fuel type that respondents intended to purchase or lease for their organization, either a replacement for a currently owned vehicle or an additional vehicle, for ZEV owners and non-ZEV owners. Whereas ZEV owners are much more likely to consider BEVs (35 percent vs 11 percent), non-ZEV owners are more likely to consider HEVs (24 percent vs 18 percent).

Table 109: Commercial ZEV Survey — Replacement Vehicle Type by ZEV Ownership (Respondents Chose up to 4 Vehicle Types)

Replacement Vehicle Type	ZEV Owner Count	ZEV Owner Percent	Non-ZEV Owner Count	Non-ZEV Owner Percent	Total Count	Total Percent
Subcompact Car	5	1.6%	30	1.7%	35	1.7%
Compact Car	33	10.3%	123	6.8%	156	7.4%
Midsize Car	85	26.6%	244	13.6%	329	15.5%
Large Car	38	11.9%	92	5.1%	130	6.1%
Sports Car	18	5.6%	55	3.1%	73	3.4%
Subcompact SUV	9	2.8%	29	1.6%	38	1.8%
Compact SUV	43	13.4%	93	5.2%	136	6.4%
Midsize SUV	132	41.3%	381	21.2%	513	24.2%
Large SUV	70	21.9%	247	13.7%	317	15%
Small Van	37	11.6%	277	15.4%	314	14.8%
Full-size Van	43	13.4%	449	24.9%	492	23.2%
Small Pickup	57	17.8%	427	23.7%	484	22.8%
Full-size Pickup	97	30.3%	874	48.6%	971	45.8%

Source: 2024 California Vehicle Survey, California Energy Commission

Table 110: Commercial ZEV Survey — Replacement Vehicle Fuel Type by ZEV Ownership (Number of Survey Responses)

Replacement Vehicle Fuel Type	ZEV Owner Count	ZEV Owner Percent age	Non-ZEV Owner Count	Non-ZEV Owner Percent	Total Count	Total Percent age
Gasoline Vehicle	176	15%	2,083	33%	2,259	30%
Hybrid Electric Vehicle (Gasoline) (HEV)	210	18%	1,547	24%	1,757	23%
Battery Electric Vehicle (BEV)	403	35%	715	11%	1,118	15%
Plug-in Hybrid Electric Vehicle (PHEV)	197	17%	889	14%	1,086	15%
Diesel Vehicle	45	4%	126	10%	670	9%
Hydrogen Fuel Cell Electric Vehicle (FCEV)	61	5%	226	4%	287	4%
Plug-in Hydrogen Fuel Cell Vehicle (PFCEV)	68	6%	241	4%	309	4%
Total	**1,160**	**100%**	**6,326**	**100%**	**7,486**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

In total, 15 percent (n=314) of the final set of commercial survey respondents completed the PHEV & BEV questionnaire. **Table 111** shows completed commercial PHEV & BEV surveys, by region, for PHEV and BEV owners.

Table 111: Commercial ZEV Survey — Completes, by Survey Region

Survey Region	Completed PHEV Surveys Count	Completed PHEV Surveys Percent	Completed BEV Surveys Count	Completed BEV Surveys Percent	Total Count	Total Percent
San Francisco	16	19.5%	55	22.3%	69	22.0%
Los Angeles	47	57.3%	119	48.2%	155	49.4%
San Diego	4	4.9%	25	10.1%	23	9.2%
Sacramento	4	4.9%	14	5.7%	17	5.4%
Central Valley	3	3.7%	21	8.5%	23	7.3%
Rest of State	8	9.8%	13	5.3%	21	6.7%
Total	**82**	**100%**	**247**	**100%**	**314**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 112 shows completed commercial PHEV and BEV surveys by self-reported vehicle fleet size, for PHEV owners and BEV owners. One-third (33 percent) of respondents reported only one commercial vehicle.

Table 112: Commercial PEV Survey — Completes, by Fleet Size

Fleet Size	Completed PHEV Surveys Count	Completed PHEV Surveys Percent	Completed BEV Surveys Count	Completed BEV Surveys Percent	Total PEV Count	Total PEV Percent
1 Vehicle	21	25.6%	83	33.6%	104	33.1%
2 Vehicles	18	22.0%	67	27.1%	82	26.1%
3-5 Vehicles	18	22.0%	45	18.2%	61	19.4%
6-9 Vehicles	5	6.1%	10	4.0%	14	4.5%
10+ Vehicles	20	24.4%	42	17.0%	53	16.9%
Total	**82**	**100%**	**247**	**100%**	**314**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial PEV Charging Behavior

PHEV and BEV respondents were also asked a series of questions about their vehicle charging behaviors. **Table 113** shows the average charging rate per kilowatt-hour for all commercial PHEV and BEV owners who chose to report their average rate. On average, respondents indicated they spent 22 cents per kilowatt-hour charging their PHEVs or BEVs or both.

Table 113: Commercial ZEV Survey — Average Charging Rate (Number of Survey Responses)

Charging Rate	Count	Percent
No cost	8	14.8%
Less than $0.25	22	40.7%
$0.25-$0.49	23	42.6%
$0.50-$0.74	1	1.9%
$0.75-$1.00	0	0%
Total	**54**	**100%**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 114 shows the frequency of the primary charging locations of commercial PHEVs and BEVs by vehicle body type. Each respondent selects one for each vehicle type they had available. Most respondents reported charging their PHEVs and BEVs on company sites.

Table 114: Commercial ZEV Survey – Primary Charging Location (Number of Survey Responses)

Vehicle Type	Primarily Company Site Chargers	Primarily Non-Company Chargers	A mix of Company and non-Company Chargers
Cars	57	11	24
SUVs	32	2	21
Vans	9	1	1
Trucks	11	0	5
Total	**109**	**14**	**51**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 115 shows the frequency of the offsite charging locations of commercial PHEVs and BEVs by vehicle type. Respondents who charge their PHEVs and BEVs offsite were most likely to do so at an employee or owner's home.

Table 115: Commercial ZEV Survey – Offsite Charging Location (Number of Survey Responses)

Vehicle Type	Primarily at Employee's /Owner's Home	Primarily at Public Charging Stations	A mix of Home and Public	Primarily at Another Location	Not Sure
Cars	49	21	36	0	5
SUVs	38	15	22	4	3
Vans	4	4	6	1	1
Trucks	12	4	5	0	1
Total	**103**	**44**	**69**	**5**	**10**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 116 shows the frequency of on-site weekday plug-in frequency of commercial PHEVs and BEVs. Most respondents reported plugging in PHEVs and BEVs at least three weekdays per week.

Table 116: Commercial ZEV Survey — On-Site Weekday Plugin Frequency (Number of Survey Responses)

Vehicle Type	Never	Less than once a week	1 or 2 times per week	3 or 4 times per week	Daily
Cars	1	3	30	18	29
SUVs	0	4	19	14	16
Vans	0	0	0	2	8
Trucks	0	0	8	3	5
Total	**1**	**7**	**57**	**37**	**58**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 117 shows the frequency of on-site weekday charge time of commercial PHEVs and BEVs. Vehicles were most likely to be charged overnight between 9 p.m. and 7 a.m. During daytime, vehicles were most likely to be charged in the afternoon between 11 a.m. and 4 p.m.

Table 117: Commercial ZEV Survey — Weekday Charge Time (Number of Survey Responses)

Vehicle Type	Morning (7am–11am)	Afternoon (11am–4pm)	Evening (4pm–9pm)	Overnight (9pm–7am)
Cars	12	19	4	45
SUVs	10	9	5	29
Vans	0	2	2	6
Trucks	3	2	0	11
Total	**25**	**32**	**11**	**91**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 118 shows the frequency of on-site weekend charge time of commercial PHEVs and BEVs. Similar to weekdays, vehicles were most likely to be charged overnight between 9 p.m. and 7 a.m.

Table 118: Commercial ZEV Survey — Weekend Charge Time (Number of Survey Responses)

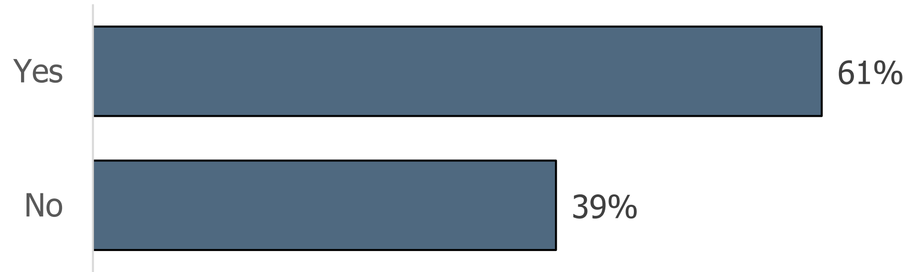
	Morning (7am–11am)	Afternoon (11am–4pm)	Evening (4pm–9pm)	Overnight (9pm7am)	Never charged on weekends
Cars	9	7	4	39	22
SUVs	5	5	4	29	10
Vans	1	1	1	5	2
Trucks	3	2	0	9	2
Total	**18**	**15**	**9**	**82**	**36**

Source: 2024 California Vehicle Survey, California Energy Commission

Commercial V2X Interest

The final questions asked in the ZEV branch of the commercial survey were about interest in V2H and V2V technology. Of ZEV respondents, 61 percent said they were interested in V2H technology to power their business location in the event of a power outage, and 58 percent said they were interested in V2V technology to charge one EV with another (**Figure 50** and **Figure 51**).

Figure 50: Commercial Interest in Powering Business Location with Electric Vehicle in the Event of a Power Outage



Source: 2024 California Vehicle Survey, California Energy Commission

Figure 51: Commercial Interest in Charging One Electric Vehicle with Another

Source: 2024 California Vehicle Survey, California Energy Commission

CHAPTER 8: Logistic Regression Analysis

This chapter describes the logistic regression modeling completed for the residential and commercial market segments using survey data. The modeling included the estimation of a system of five equations describing vehicle ownership and use for households and two equations describing vehicle type choice for commercial vehicle fleets. The project team estimated additional models using different specifications that can be found in the appendix volume.

The model specifications are described separately in this document. The discussion related to each model includes a description of the type of data used to estimate the model, the variables that were included in the utility functions (including any transformations of the variables), the coefficient estimates, and model fit statistics.

The model structure and output presented in this report are at a statewide level and reflect specifications that are constrained to match the specifications currently programmed in the forecasting software. Specification tests with urban and regional variables are included in Appendix A. Additional unconstrained specification tests for various models that could be used in future forecasting applications will be documented separately and provided to the commission agreement manager.

Residential Models Overview

Six interrelated models were estimated using the residential CVS data to support a model known as Personal Vehicle Choice (PVC) that is used to forecast light-duty vehicle demand:

1. **Vehicle type choice model**
    - The residential vehicle type choice model is a multinomial logit (MNL) model that reflects preferences for different vehicle attributes and is used to estimate household vehicle utility based on these attributes (e.g., price, vehicle type, fuel type). The PVC model segments the residential population by the number of vehicles that the households own; this segmentation technique has resulted in statistically significant differences in models among the segments. The current version of PVC supports three household vehicle ownership segments: 1) one vehicle, 2) two vehicles, and 3) three or more vehicles.
2. **Autonomous vehicle choice model**
    - The residential autonomous vehicle choice model is a joint multinomial logit (MNL) model that reflects preferences for different levels of vehicle autonomy and is used to estimate household vehicle utility based on all the attributes in the vehicle type choice model and levels of autonomy.
3. **Vehicle transaction and replacement choice model**
    - The vehicle transaction and replacement choice model use a nested MNL form to estimate the probability that a household will choose to replace a vehicle. This model was estimated using the RP survey data, and a single model was fitted to households owning one, two, or three or more vehicles.

4. **New-used vehicle choice model**
    - The new-used vehicle choice is a fractional logistic model that reflects preferences for new vehicles compared to used vehicles and is used to estimate the probability that a household will select a new vehicle as their next purchase or lease. This model was specified using SP data with separate models for households owning one, two, or three or more vehicles.
5. **Vehicle quantity choice model**
    - The vehicle quantity choice model uses the RP survey data to predict the probability that a household owns zero, one, two, or three or more vehicles using a multinomial logit model.
6. **Vehicle miles traveled (VMT) regression model**
    - The VMT equation uses the RP survey data to model the self-reported annual VMT of each household vehicle; these results were fitted separately to households owning one, two, or three or more vehicles.

Residential Vehicle Choice Model

The project team merged residential household information from the RP survey data with the SP survey data to estimate the vehicle type choice model. In the SP survey, respondents answered eight vehicle choice questions, each of which was considered an experiment. Each experiment presented respondents with four hypothetical vehicle alternatives: Vehicle A, Vehicle B, Vehicle C, and Vehicle D. These four vehicles were described using a set of 16 attributes.

The dataset included only households with one or more vehicles. The final dataset used to fit the vehicle choice model contained 30,400 observations from 3,800 respondents.

The new or used vehicles the respondents planned to purchase next for their households were based on their responses in the RP survey — or the reference vehicle — and were always presented as one of the vehicle alternatives. The project team randomized the order of the alternatives from one experiment to the next to minimize potential order bias. As a result, the reference vehicle could be presented as Vehicle A, Vehicle B, Vehicle C, or Vehicle D in any given experiment.

The vehicle attributes presented for the nonreference alternative varied according to the experimental design discussed in Chapter 3 and Appendix C. Respondents were asked to select the vehicle they would most likely purchase based on the attribute levels presented for each of the four alternatives. **Figure 52** presents a sample choice experiment. Detailed information about the alternatives, attributes, levels, and experimental design used in the SP survey can be found in Chapter 3 and Appendix C.

Figure 52: Sample SP Vehicle Type Choice Experiment

Please carefully review each vehicle and all its features below. Assuming these are the only vehicles available to you to purchase, please select the ONE vehicle you would most likely purchase. Please hover-over each feature, if you are not familiar with it, to see description.

		Vehicle A	Vehicle B	Vehicle C	Vehicle D
Vehicle Class		Midsize Car	Midsize Car	Small Pickup Truck	Compact Car
Fuel Type		BEV	Gasoline only	PFCV	FCV
Brand Type		Standard	Standard	Standard	Premium
Model Year		New	New	New	New
Purchase Price		$32,700	$36,400	$60,600	$56,700
Vehicle Range		252 miles	594 miles	410 miles (hydrogen) 20 miles (electric)	618 miles
Fuel Stations			Gasoline stations (at today's locations)	10 miles to station from home/work	10 miles to station from home/work
Public charging locations	Level 2	Public level 2 chargers are 15 minutes away		Public level 2 chargers are 15 minutes away	
	Fast	Public fast chargers are 30 minutes away with an average wait time of 45 minutes		Public fast chargers are 30 minutes away with an average wait time of 45 minutes	
Home Charging		Not Available		Not Available	
Work Charging		Not Available		Not Available	
MPGe		141 miles	31 miles	52 miles (hydrogen) 91 miles (electric)	45 miles
Fuel Cost per 100 miles (Public Station fuel)		$6.60	$9.00	$32.00 (hydrogen) $10.30 (electric)	$37.40
Refueling Time (Public Stations)		8 hours to charge from 10% to 80 % (Level 2) 30 minutes to charge from 10% to 80% (DC Fast)	5 mins	5 mins (hydrogen) 40 minutes for 10 miles for regular charging (electric)	5 mins
Purchase Incentive		$1,000 Rebate	None	$2,500 Rebate	$2,500 Rebate
Annual Maintenance Cost		$530	$590	$400	$830
Acceleration (0-60 mph)		6.4	8.4	2.7	4.9
		○	○	○	○

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<< Previous Next >>

Source: 2024 California Vehicle Survey, California Energy Commission

Residential Vehicle Type Choice Model Specification

The project team modeled the choice among the four vehicle alternatives using a multinomial logit model form. Coefficients of this logit model form were estimated for different utility function specifications. All the specifications included the vehicle attributes that were varied in the SP experiments, household characteristics, and constants for different vehicle types, vehicle sizes, and fuel options. Other constants and interactions were tested to reduce bias and improve model fit. Interpretation and discussion of each set of parameters follow below.

Constants

The project team tested several alternative-specific and reference vehicle constants in the vehicle type choice utility specification to remove potential bias from the coefficient estimates.

A reference vehicle constant was included on the choice option that matched the specifications of the respondent's next vehicle purchase in the RP survey. Constants were also included on the three additional alternatives to capture any unobserved utility compared to the reference vehicle. The inertia constants are not intended for use in forecasting.

Vehicle Type

Vehicle type refers to different combinations of size and body type. The project team estimated coefficients for 12 of the 13 vehicle types presented in the SP experiments. The coefficient for subcompact cars was constrained to zero, and the remaining vehicle type coefficients were estimated relative to the subcompact car coefficient. A positive value for a given vehicle type indicated that, all else being equal, the vehicle type was preferred to subcompact, while a negative value indicated that subcompact is preferred to that vehicle. For all households, midsize SUVs were the most preferred vehicle type.

Fuel Type

Fuel type refers to different combinations of vehicle fuel and technology types, such as gasoline, gasoline-electric hybrid, plug-in hybrid electric, etc. The gasoline fuel type coefficient was constrained to zero, and the remaining six fuel type coefficients were estimated relative to gasoline. For all households, gasoline HEVs were most preferred, but the coefficient estimate was only statistically significant at conventional levels for two-vehicle households. Based on the hypothesis tests, BEVs were as preferred as gasoline vehicles for all households.

Prestige

Brand prestige was included in the experiments at two levels: standard and premium. Participants were given examples of standard and premium brands listed in **Table 119**. The baseline in the model is standard, so a positive estimate for premium indicates an increased utility for premium relative to standard make.

Table 119: Prestige Examples

Standard Makes	Premium Makes
Buick	Acura
Chevrolet	Audi
Chrysler	BMW
Dodge	Cadillac
Ford	Fisker
GMC	Genesis
Honda	Hummer
Hyundai	Infiniti
Jeep	Jaguar
Kia	Land Rover

Standard Makes	Premium Makes
Mazda	Lexus
Mercury	Lincoln
Mini	Lucid
Mitsubishi	Mercedes-Benz
Nissan	Polestar
Pontiac	Porsche
Saturn	Rivian
Smart	Saab
Subaru	Tesla
Suzuki	Volvo
Toyota	
Volkswagen	

Source: 2024 California Vehicle Survey, California Energy Commission

Vehicle Age

Vehicle age was presented as three categories in the experiments:

1. New vehicles (Model Year 2024)
2. Used vehicles (three years old)
3. Used vehicles (six years old)

The coefficient for new vehicles was constrained to zero so that the two used vehicle coefficient values were relative to new vehicles. The negative values for both used vehicle categories indicate that, all else being equal, new vehicles are preferred to used vehicles.

Incentives

The project team estimated coefficients for each of the four incentives shown in the SP experiments, with the coefficient for the no-incentive level constrained to zero. The estimated coefficients for the remaining three incentives, including high-occupancy vehicle (HOV) lane use, tax credit, and rebate were relative to the base level of no incentive. The HOV lane incentive was represented as a dummy (0,1) variable, while the tax credit and rebate terms were specified in thousands of dollars.

Vehicle Purchase Price

Vehicle purchase price was expressed in thousands of dollars and interacted with the ratio of the respondents' annual household income to the mean household income for each ownership category to identify how sensitivity to price varied with income. The negative value on the coefficient suggests that as price increases, the effect on the respondent's utility is negative. In the RP survey, household income was reported in income ranges. To fit the model, each income range was represented by the midpoint value for that range, as shown in **Table 120**.

Several linear and nonlinear income transformations were tested. In the selected model, income is used with a power transformation (λ) that is estimated with the data itself. Rather than using a log transformation that imposes a single functional form on the income variable, this transformation is defined by the relationship between income and price in the data itself.[3]

At the mean income level, the effect of price is always equal to the value of the coefficient. At income levels below or above the mean, the effect of price is a function of both the income level and the estimated value of the power transformation (λ). If λ is equal to 0, the effect of price is equal to the coefficient, but if λ is less than 0, then the effect of price is equal to the inverse ratio between income and mean income. For instance, for a household whose income is one half of the mean income, and an estimated power transformation of -3, the effect of price is the price coefficient times 8, and for a household whose income is double the mean income, the effect of price is the price coefficient divided by 8.

Table 120: Income Ranges and Midpoint Values

Income Range	Income Midpoint
Less than $9,999	$5,000
$10,000 to $24,999	$17,500
$25,000 to $34,999	$30,000
$35,000 to $49,999	$42,500
$50,000 to $74,999	$62,500
$75,000 to $99,999	$87,500
$100,000 to $149,999	$125,000
$150,000 to $199,999	$175,000
$200,000 to $249,999	$225,000
$250,000 or More	$275,000

Source: 2024 California Vehicle Survey, California Energy Commission

Maintenance Cost and Fuel Cost

Maintenance cost was presented and estimated in the experiments in units of dollars per year. The maintenance cost attribute was transformed using the natural log of thousands of dollars. Fuel cost was presented in the experiments in units of dollars per 100 miles. For vehicles with two fuel types (PHEVs and PFCVs) fuel cost is calculated by adding 60 percent of the cost for electricity and 40 percent of the cost for either gasoline or hydrogen. The negative values of both coefficients indicate the disutility, or adverse effects, of increasing operating costs.

Miles per Gallon

The miles per gallon coefficient represents the value of the fuel efficiency of a vehicle. The units are in miles per gallon equivalent (MPGe). The project team calculated and presented fuel economy for liquid fuels (gasoline and diesel) as actual miles per gallon. For other fuels (electricity, and hydrogen), fuel economy was determined in miles per gasoline gallon equivalent (MPGe). An MPGe is the amount of the alternative fuel that provides the same energy content as one gallon of gasoline. For vehicles with two fuel types (PHEVs and PFCVs) this value is calculated by adding 60 percent of the MPGe for electricity and 40 percent of the

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3 See Axhausen, Kay W., Stephane Hess, Arnd König, Georg Abay, John J. Bates, and Michel Bierlaire. 2008. "Income and Distance Elasticities of Values of Travel Time Savings: New Swiss Results." *Transport Policy* 15 (3, May): 173–185 for more discussion of this transformation in choice modeling.

MPG or MPGe for either gasoline or hydrogen. In the results, this calculation is referred to as the *weighted MPGe.* A positive value indicates that vehicle utility increases as MPGe increases.

Acceleration

The *acceleration coefficient* represents the value of vehicle acceleration from 0 to 60 miles per hour and measured in units of seconds. A positive value indicates that vehicle utility increases as acceleration increases.

Refueling Locations/Station Availability

The SP survey included attributes that described refueling locations for all fuels and technologies. Refueling at a station was the only option for all gasoline vehicles, diesel vehicles, and HEVs. Diesel availability was measured as a percent of fuel stations that offer diesel fuel. PHEVs and BEVs were presented with the options of refueling at home, work, or at a charging station (both Level 2 and fast charging for work and public charging for BEVs). Charging options were shown in tandem with the amount of time (in minutes) required to reach the closest location and the wait time to use a fast charger after arriving at the location. Fuel cell vehicles (FCVs) were presented with the distance to hydrogen fueling station in miles. The attributes for station type, time-to-station, and wait time were designed to realistically represent the options available to drivers of each of the specific fuel types and technologies.

Refueling Time

Refueling time represents the time needed to refuel (fill the tank) a vehicle. This attribute varied based on fuel type as with the fuel availability attribute. PHEVs, BEVs, and PFCVs were presented with refueling times from 15 minutes to 12 hours, while gasoline, HEV, diesel, and FCV vehicles were presented with a time of 5 minutes. A negative coefficient value implies that faster refueling times are viewed more favorably, all else being equal.

Range

Range represents the distance in miles a vehicle can travel (on a full tank) before refueling is required. Different range levels were presented for each of the fuel types, although all values were presented in miles. The natural log of range in miles is included in the final model specification. This transformation indicates that additional range provides more benefit at lower range values. For example, an increase in vehicle range from 50 to 100 miles provides more utility than an increase in range from 250 to 300 miles.

Regional Coefficients

The vehicle choice model was segmented by region to identify regional differences in preferences for vehicle type and fuel type. The six California regions were composed of different counties, as shown in **Table 121**. The survey regions included the four major metropolitan areas of San Francisco, Los Angeles, San Diego, and Sacramento, and the Fresno/Central Valley region. A sixth region encompassed the rest of the state outside these areas. These regional models are presented in the appendix to this report.

Table 121: California Survey Regions

Region Number	Region Name	Counties in Region
1	**San Francisco**	Alameda, Contra Costa, Marin, Napa, San Mateo, Santa Clara, Solano, Sonoma, and San Francisco
2	**Los Angeles**	Los Angeles, Orange, Imperial, Riverside, San Bernardino, and Ventura
3	**San Diego**	San Diego
4	**Sacramento**	El Dorado, Placer, Sacramento, Sutter, Yolo, and Yuba
5	**Central Valley**	Fresno, Kern, Kings, Madera, Merced, San Joaquin, Stanislaus Tulare
6	**Rest of State**	Alpine, Amador, Butte, Calaveras, Colusa, Del Norte, Glenn, Humboldt, Inyo, Lake, Lassen, Mariposa, Mendocino Modoc, Mono, Monterey, Nevada, Plumas, San Benito, San San Luis Obispo, Santa Barbara, Santa Cruz, Shasta, Sierra, Siskiyou, Tehama, Trinity, and Tuolumne

Source: 2024 California Vehicle Survey, California Energy Commission

Residential Vehicle Type Choice Model

Table 122 presents the coefficient values and t-statistics for the model specification for the three household vehicle ownership categories. **Table 123** presents the fit statistics for each of the three residential vehicle choice models.

Table 122: Residential Vehicle Type Choice Model Coefficients, by Ownership Category

Para meter	Variable	Units	1 Veh Coef.	1 Veh T-Stat	2 Veh Coef.	2 Veh T-Stat	3+ Veh Coef.	3+ Veh T-Stat
α1	Reference vehicle (from consideration set)	-	0.000	NA	0.000	NA	0.000	NA
α2	First non-reference vehicle	-	-0.912	-26.081	-1.020	-31.291	-1.131	-24.251
α3	Second non-reference vehicle	-	-1.095	-27.922	-1.180	-32.788	-1.309	-25.519
α4	Third non-reference vehicle	-	-1.516	-34.216	-1.547	-38.999	-1.655	-27.737
β1,1	Subcompact Car	0,1	0.000	NA	0.000	NA	0.000	NA
β1,2	Compact Car	0,1	0.256	3.166	0.085	1.072	0.129	0.958
β1,3	Midsize Car	0,1	0.249	3.051	0.399	5.062	0.451	3.534
β1,4	Large Car	0,1	-0.015	-0.155	0.075	0.789	0.219	1.483
β1,5	Sports Car	0,1	0.249	2.506	0.082	0.828	0.180	1.139
β1,6	Subcompact Crossover	0,1	0.216	2.521	0.172	2.001	0.264	1.976
β1,7	Compact Crossover	0,1	0.237	2.993	0.372	4.510	0.546	4.115
β1,8	Midsize Crossover/SUV	0,1	0.607	7.080	0.723	8.537	0.915	6.656
β1,9	Large SUV	0,1	0.191	1.790	0.355	3.504	0.725	4.633
β1,10	Small Van	0,1	-0.074	-0.709	0.127	1.276	0.152	0.981
β1,11	Full-size/large Van	0,1	-0.271	-2.381	-0.007	-0.066	-0.005	-0.031
β1,12	Small Pickup Truck	0,1	0.078	0.810	0.106	1.125	0.329	2.199
β1,13	Full-size/large Pickup Truck	0,1	0.227	2.059	0.411	3.939	0.756	4.947
β2,1	Gasoline only	0,1	0.000	NA	0.000	NA	0.000	NA
β2,2	Gas HEV	0,1	-0.104	-1.820	-0.029	-0.532	-0.259	-3.421
β2,3	PHEV	0,1	-0.510	-2.561	-0.878	-4.651	-1.186	-4.227
β2,4	Diesel	0,1	-0.634	-3.908	-0.853	-5.620	-0.577	-3.247
β2,5	BEV	0,1	-0.145	-0.430	-0.392	-1.254	-0.533	-1.364
β2,6	FCV	0,1	-0.382	-1.232	-0.723	-2.527	-0.835	-2.374
β2,7	PFCV	0,1	-0.695	-1.930	-1.634	-4.846	-1.645	-3.683
β3,1	Standard	0,1	0.000	NA	0.000	NA	0.000	NA
β3,2	Premium	0,1	0.032	0.510	0.215	3.917	0.195	2.152

Para meter	Variable	Units	1 Veh Coef.	1 Veh T-Stat	2 Veh Coef.	2 Veh T-Stat	3+ Veh Coef.	3+ Veh T-Stat
β4,1	New	0,1	0.000	NA	0.000	NA	0.000	NA
β4,2	Used (3 Years Old)	0,1	-0.287	-5.526	-0.273	-5.887	-0.329	-4.691
β4,3	Used (6 Years Old)	0,1	-0.488	-6.667	-0.596	-8.918	-0.591	-5.555
β5	ln(Vehicle price) *((income/mean income)^λ)	Price in ln ($1000)	-0.438	-7.110	-0.522	-9.410	-0.454	-5.133
	Vehicle price for income less than $20,000		-0.568		-0.947		-0.515	
	Vehicle price for income $20,000 to $39,999		-0.501		-0.739		-0.489	
	Vehicle price for income $40,000 to $59,999		-0.473		-0.658		-0.478	
	Vehicle price for income $60,000 to $79,999		-0.455		-0.610		-0.470	
	Vehicle price for income $80,000 to $99,999		-0.442		-0.576		-0.465	
	Vehicle price for income $100,000 to $119,999		-0.432		-0.551		-0.460	
	Vehicle price for income $120,000 or more		-0.428		-0.540		-0.458	
β6	Total Range	ln (Miles)	0.062	1.275	0.271	5.564	0.239	3.363
β7	Share of stations with diesel	%	0.138	0.473	-0.375	-1.422	-0.064	-0.207
β8	Distance to hydrogen station	Miles	-0.005	-1.352	-0.008	-2.441	-0.001	-0.268
β9,1	Distance to Level 2 charger	Minutes	-0.003	-0.752	-0.004	-0.913	0.005	0.830
β9,2	Distance to Fast charger	Minutes	0.000	-0.011	-0.002	-0.398	-0.001	-0.240
β9,3	Wait time for Fast charger	Minutes	-0.002	-1.112	-0.002	-0.784	0.002	0.507
β10,1	No home charging	0,1	0.000	NA	0.000	NA	0.000	NA
β10,2	Home charging	0,1	0.655	4.928	0.769	8.826	0.495	4.140
β11,1	No work charging	0,1	0.000	NA	0.000	NA	0.000	NA
β11,2	Work charging: Level 2	0,1	0.017	0.279	0.113	1.911	-0.041	-0.496
β11,3	Work charging: Fast	0,1	0.058	0.899	0.082	1.309	-0.069	-0.737

Para meter	Variable	Units	1 Veh Coef.	1 Veh T-Stat	2 Veh Coef.	2 Veh T-Stat	3+ Veh Coef.	3+ Veh T-Stat
β12	MPG or MPGe	Miles per gallon	0.006	4.554	0.003	2.347	0.005	2.497
β13	Fuel cost per 100 miles	ln ($1000)	-0.096	-1.486	-0.080	-1.388	-0.226	-2.739
β14,1	Level 2 charge time to go 10 miles	Minutes	0.001	0.284	-0.002	-0.555	-0.007	-1.568
β14,2	Level 2 charge time 10% to 80% charge	Hours	-0.014	-1.537	-0.012	-1.469	0.001	0.070
β14,3	Fast charge time 10% to 80% charge	Minutes	-0.004	-2.178	-0.001	-0.834	-0.004	-1.825
β15,1	No purchase incentive	0,1	0.000	NA	0.000	NA	0.000	NA
β15,2	HOV lane incentive	0,1	0.020	0.275	0.003	0.038	0.197	1.904
β15,3	Tax incentive	$1000s	0.019	2.123	0.018	2.123	0.039	3.155
β15,4	Rebate incentive	$1000s	0.034	2.938	0.017	1.399	0.035	2.225
β16	Annual maintenance	ln ($1000)	-0.285	-4.281	-0.262	-4.301	-0.359	-4.106
β17	0-60 MPH acceleration	Seconds	0.011	0.962	-0.006	-0.619	-0.015	-1.004
λ	Power transformation for income effect	-	-0.114	-1.813	-0.226	-3.961	-0.047	-0.438

Source: 2024 California Vehicle Survey, California Energy Commission

Table 123: Residential Vehicle Type Choice Model Fit Statistics

Fit Statistics	1 Vehicle	2 Vehicles	3+ Vehicles
Number of Estimated Parameters	45	45	45
Number of Observations	11192	12872	6336
Number of Individuals	1399	1609	792
Null Log-Likelihood	-12943.14	-14644.5	-7076.88
Final Log-Likelihood	-11954.23	-13398.26	-6402.29
Adjusted Rho-Square	0.2266	0.2466	0.266

Source: 2024 California Vehicle Survey, California Energy Commission

Based on the model specification and coefficient values outlined above, the probability of a household selecting vehicle *i,* with vehicle type *v*, fuel type *f*, age *a* is given by the following equation:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_j}},$$

where U_i is the modeled utility of vehicle i, given by the following equation:

$$U_i = \alpha_i + \sum_{v=1}^{13} \beta_{1,v} X_{1,v} + \sum_{f=1}^{7} \beta_{2,f} X_{2,f} + \sum_{p=1}^{2} \beta_{3,p} X_{3,p} + \sum_{a=1}^{3} \beta_{4,a} X_{4,a} +$$

$$+ \beta_5 X_5 (inc/mean\_inc)^{\wedge}\lambda + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_{9,1} X_{9,1} + \beta_{9,2} X_{9,2} + \beta_{9,3} X_{9,3} + \beta_{10,1} X_{10,1} + \beta_{10,2} X_{10,2} + \beta_{11,1} X_{11,1} + \beta_{11,2} X_{11,2} + \beta_{11,3} X_{11,3} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14,1} X_{14,1} + \beta_{14,2} X_{14,2} + \beta_{14,3} X_{14,3} + \beta_{15,1} X_{15,1} + \beta_{15,2} X_{15,2} + \beta_{15,3} X_{15,3} + \beta_{15,4} X_{15,4} + \beta_{16} X_{16} + \beta_{17} X_{17}$$

The terms in this equation are defined as follows:

α_i = An constant for each alternative in the DCE

$X_{1,v}$ = Array of dummy variables equal to 1 when vehicle type = *v*, otherwise 0

$X_{2,f}$ = Array of dummy variables equal to 1 when fuel type = *f*, otherwise 0

$X_{3,p}$ = Array of dummy variables equal to 1 when prestige = *p*, otherwise 0; available values for *p* are "standard" and "premium."

$X_{4,a}$ = Array of dummy variables equal to 1 when vehicle age = a, otherwise 0; available values for *a* are "new," "used (three years old)," and "used (six years old)."

X_5 = Purchase price of the vehicle ($1000, natural log)

inc = Mid-point of annual household income range of the household (dollars)

mean_inc = Mean of household income of respondents in each ownership category (dollars)

X_6 = Average range of the vehicle at 100 percent fueled (natural log of miles)

X_7 = Proportion of gas stations that have diesel fuel

X_8 = Distance to a hydrogen fuel station miles)

$X_{9,1}$ = Distance to a Level 2 charger (minutes)

$X_{9,2}$ = Distance to a Level 3 fast charger (minutes)

$X_{9,3}$ = Wait time for a Level 3 fast charger (minutes)

$X_{10,2}$ = A dummy variable that equals 1 if a home has access to a home charger, 0 otherwise

$X_{11,2}$ = A dummy variable that equals 1 if a respondent has access to a Level 2 charger at work, 0 otherwise

$X_{11,3}$ = A dummy variable that equals 1 if a respondent has access to a Level 3 fast charger at work, 0 otherwise

X_{12} = MPG or MPGe for the vehicle (weighted average 60 percent electric and 40 percent gas for PHEVs, and 60 percent electric and 40 percent hydrogen for PFCVs)

X_{13} = Fuel cost per 100 miles for the vehicle (weighted average 60 percent electric and 40 percent gas for PHEVs, and 60 percent electric and 40 percent hydrogen for PFCVs, $1000, natural log)

$X_{14,1}$ = Time to charge the vehicle enough to drive 10 miles with a Level 2 charger (minutes)

$X_{14,2}$ = Time to charge the vehicle from 10 percent to 80 percent with a Level 2 charger (hours)

$X_{14,3}$ = Time to charge the vehicle from 10 percent to 80 percent with a Level 3 fast charger (minutes)

$X_{15,2}$ = A dummy variable that equals 1 if the vehicle qualifies for access to the HOV lanes, 0 otherwise

$X_{15,3}$ = The value of a tax incentive for the vehicle ($1000)

$X_{15,4}$ = The value of a rebate incentive for the vehicle ($1000)

X_{16} = Average annual maintenance costs for the vehicle ($1000, natural log)

X_{17} = Average time to accelerate from 0 to 60 MPH (seconds)

The denominator term is the sum of exponentiated utilities for all vehicles in the respondent's choice set, which includes all vehicle types and fuel types available for each model year.

In this model, the vehicle class associated with the highest levels of utility are midsize crossover SUVs. BEVs are associated with approximately the same utility for respondents as gasoline vehicles for all ownership categories. The presence of a home charger is the strongest predictor of increasing utility for electric vehicles. Tax and rebate incentives for ZEVs add significant utility, but HOV lane access does not, and increasing annual maintenance costs are associated with significant disutility for all ownership categories.

Table 122 also includes the effect of price at seven income levels. These estimates were calculated with the following formula:

$$est = \beta_5 * (inc/mean\_inc)^\wedge\lambda$$

Where est equals the estimated effect of price at a given income levels, inc equals the income level for the estimate, $mean\_inc$ equals the mean income for the ownership category, summarized in **Table 124**, and β_5 and λ are parameters estimated in **Table 122**.

Table 124: Mean Income Values for Each Ownership Category

	1 Vehicle	2 Vehicles	3+ Vehicles
Mean Income	$97,542.89	$139,425.10	$150,154.70

Source: 2024 California Vehicle Survey, California Energy Commission

Residential Vehicle Type Choice Model Coefficients — ZEV-Fuel Type Interactions

The residential vehicle choice model was estimated separately to include an interaction term between a dummy variable that indicates whether the respondent owns a ZEV and the ZEV fuel type (BEV, PHEV, FCEV, and PFCEV) variables. The coefficients for the ZEV-fuel-type interaction model are presented in **Table 125,** and the model fit statistics are presented in **Table 126**.

Table 125: Residential ZEV Fuel-Type Vehicle Choice Model Coefficients

Parameter	Variable	Units	1 Veh Coef.	1 Veh T-Stat	2 Veh Coef.	2 Veh T-Stat	3+ Veh Coef.	3+ Veh T-Stat
α_1	Reference vehicle (from consideration set)	-	0.000	NA	0.000	NA	0.000	NA
α_2	First non-reference vehicle	-	-0.892	-25.601	-0.987	-30.389	-1.098	-23.442
α_3	Second non-reference vehicle	-	-1.075	-27.385	-1.144	-31.802	-1.274	-24.981
α_4	Third non-reference vehicle	-	-1.491	-33.746	-1.509	-37.956	-1.622	-27.012
$\beta_{1,1}$	Subcompact Car	0,1	0.000	NA	0.000	NA	0.000	NA
$\beta_{1,2}$	Compact Car	0,1	0.251	3.106	0.089	1.117	0.131	0.969
$\beta_{1,3}$	Midsize Car	0,1	0.243	2.974	0.398	5.021	0.446	3.488
$\beta_{1,4}$	Large Car	0,1	-0.016	-0.159	0.078	0.821	0.227	1.532
$\beta_{1,5}$	Sports Car	0,1	0.245	2.472	0.097	0.978	0.190	1.205
$\beta_{1,6}$	Subcompact Crossover	0,1	0.213	2.480	0.168	1.939	0.263	1.957
$\beta_{1,7}$	Compact Crossover	0,1	0.238	3.020	0.374	4.497	0.552	4.152
$\beta_{1,8}$	Midsize Crossover/SUV	0,1	0.613	7.141	0.731	8.577	0.919	6.656
$\beta_{1,9}$	Large SUV	0,1	0.193	1.805	0.371	3.643	0.734	4.678
$\beta_{1,10}$	Small Van	0,1	-0.071	-0.679	0.137	1.369	0.154	0.991
$\beta_{1,11}$	Full-size/large Van	0,1	-0.264	-2.315	0.005	0.043	0.005	0.027
$\beta_{1,12}$	Small Pickup Truck	0,1	0.078	0.803	0.110	1.162	0.333	2.230
$\beta_{1,13}$	Full-size/large Pickup Truck	0,1	0.224	2.029	0.419	3.981	0.765	4.997
$\beta_{2,1}$	Gasoline only	0,1	0.000	NA	0.000	NA	0.000	NA
$\beta_{2,2}$	Gas HEV	0,1	-0.103	-1.792	-0.019	-0.355	-0.251	-3.311
$\beta_{2,3}$	PHEV	0,1	-0.586	-2.926	-0.933	-4.870	-1.366	-4.817
$\beta_{2,4}$	PHEV x (ZEV owner)	0,1	0.571	3.917	0.395	3.753	0.542	3.780
$\beta_{2,5}$	Diesel	0,1	-0.624	-3.844	-0.841	-5.536	-0.594	-3.321
$\beta_{2,6}$	BEV	0,1	-0.260	-0.767	-0.648	-2.048	-0.874	-2.176
$\beta_{2,7}$	BEV x (ZEV owner)	0,1	0.710	4.403	0.846	7.271	0.758	4.840
$\beta_{2,8}$	FCV	0,1	-0.440	-1.409	-0.830	-2.849	-0.991	-2.803
$\beta_{2,9}$	FCV x (ZEV owner)	0,1	0.455	2.748	0.347	2.710	0.338	1.905
$\beta_{2,10}$	PFCV	0,1	-0.746	-2.060	-1.744	-5.134	-1.665	-3.671
$\beta_{2,11}$	PFCV x (ZEV owner)	0,1	0.480	2.839	0.516	3.962	0.007	0.036

Parameter	Variable	Units	1 Veh Coef.	1 Veh T-Stat	2 Veh Coef.	2 Veh T-Stat	3+ Veh Coef.	3+ Veh T-Stat
$\beta_{3,1}$	Standard	0,1	0.000	NA	0.000	NA	0.000	NA
$\beta_{3,2}$	Premium	0,1	0.033	0.517	0.220	3.984	0.194	2.158
$\beta_{4,1}$	New	0,1	0.000	NA	0.000	NA	0.000	NA
$\beta_{4,2}$	Used (3 Years Old)	0,1	-0.286	-5.505	-0.271	-5.838	-0.331	-4.707
$\beta_{4,3}$	Used (6 Years Old)	0,1	-0.488	-6.636	-0.602	-8.987	-0.596	-5.587
β_5	ln(Vehicle price) * ((income/mean income) ^ λ)	Price in ln ($1000)	-0.444	-7.147	-0.528	-9.454	-0.464	-5.229
	Vehicle price for income less than $20,000		-0.558		-0.923		-0.520	
	Vehicle price for income $20,000 to $39,999		-0.500		-0.731		-0.496	
	Vehicle price for income $40,000 to $59,999		-0.475		-0.656		-0.486	
	Vehicle price for income $60,000 to $79,999		-0.459		-0.611		-0.479	
	Vehicle price for income $80,000 to $99,999		-0.448		-0.579		-0.474	
	Vehicle price for income $100,000 to $119,999		-0.439		-0.555		-0.470	
	Vehicle price for income $120,000 or more		-0.435		-0.545		-0.469	
β_6	Total Range		0.064	1.320	0.269	5.543	0.242	3.429
β_7	Share of stations with diesel	%	0.154	0.528	-0.374	-1.412	-0.106	-0.341
β_8	Distance to hydrogen station	Miles	-0.005	-1.354	-0.008	-2.416	-0.001	-0.263
$\beta_{9,1}$	Distance to Level 2 charger	Minutes	-0.003	-0.698	-0.004	-0.870	0.006	0.916
$\beta_{9,2}$	Distance to Fast charger	Minutes	0.001	0.194	-0.002	-0.361	0.000	0.024
$\beta_{9,3}$	Wait time for Fast charger	Minutes	-0.003	-1.196	-0.002	-0.706	0.001	0.319
$\beta_{10,1}$	No home charging	0,1	0.000	NA	0.000	NA	0.000	NA
$\beta_{10,2}$	Home charging	0,1	0.193	1.401	0.338	3.348	0.139	1.079
$\beta_{11,1}$	No work charging	0,1	0.000	NA	0.000	NA	0.000	NA

Parameter	Variable	Units	1 Veh Coef.	1 Veh T-Stat	2 Veh Coef.	2 Veh T-Stat	3+ Veh Coef.	3+ Veh T-Stat
$\beta_{11,2}$	Work charging: Level 2	0,1	0.012	0.197	0.106	1.739	-0.053	-0.631
$\beta_{11,3}$	Work charging: Fast	0,1	0.064	0.986	0.080	1.250	-0.076	-0.794
β_{12}	MPG or MPGe	Miles per gallon	0.006	4.692	0.003	2.647	0.005	2.598
β_{13}	Fuel cost per 100 miles	ln ($1000)	-0.097	-1.505	-0.079	-1.356	-0.222	-2.666
$\beta_{14,1}$	Level 2 charge time to go 10 miles	Minutes	0.001	0.274	-0.002	-0.555	-0.006	-1.485
$\beta_{14,2}$	Level 2 charge time 10% to 80% charge	Hours	-0.013	-1.441	-0.013	-1.636	0.002	0.138
$\beta_{14,3}$	Fast charge time 10% to 80% charge	Minutes	-0.004	-2.235	-0.002	-1.060	-0.004	-1.811
$\beta_{15,1}$	No purchase incentive	0,1	0.000	NA	0.000	NA	0.000	NA
$\beta_{15,2}$	HOV lane incentive	0,1	0.024	0.313	0.005	0.070	0.183	1.730
$\beta_{15,3}$	Tax incentive	$1000	0.020	2.157	0.020	2.313	0.040	3.146
$\beta_{15,4}$	Rebate incentive	$1000	0.035	3.008	0.016	1.298	0.036	2.255
β_{16}	Annual maintenance cost	ln ($1000)	-0.286	-4.292	-0.267	-4.371	-0.356	-4.053
β_{17}	0-60 MPH acceleration	Seconds						
λ	Power Transformation for Income Effect	-	-0.100	-1.570	-0.212	-3.662	-0.042	-0.393

Source: 2024 California Vehicle Survey, California Energy Commission

Table 126: Residential ZEV-Fuel Type Vehicle Choice Model Fit Statistics

Fit Statistics	1 Vehicle	2 Vehicles	3+ Vehicles
Number of Observations	11192	12872	6336
Number of Individuals	1399	1609	792
Null Log-Likelihood	-12943.14	-14644.5	-7076.88
Final Log-Likelihood	-11929.69	-13342.79	-6374.65
Adjusted Rho-Square	0.2279	0.2495	0.2687

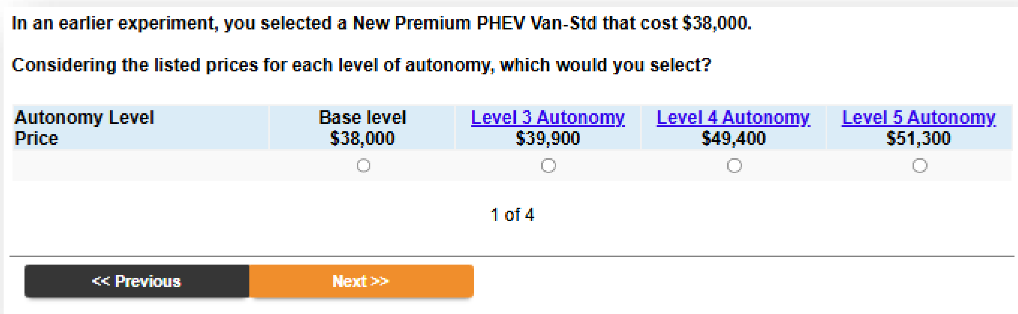
Source: 2024 California Vehicle Survey, California Energy Commission

In these models, ZEV owners in all households are more likely to choose a PHEV and ZEV, and 1- and 2-vehicle households are more likely to choose a FCEV and PFCEV.

Residential Autonomous Vehicle Choice Models

The 2024 CVS included a new DCE that asked all survey participants to respond to an additional slate of four stated preference questions. In each of these questions, respondents were shown one of the vehicles they had previously selected in the vehicle choice experiments and asked at which level of autonomy the respondent would prefer to purchase the vehicle. Vehicle prices for increasing levels of autonomy increased in each experiment, but by varying amounts. **Figure 53** shows an example of this experiment.

Figure 53: Autonomous Vehicle Choice Experiment Example



Source: 2024 California Vehicle Survey, California Energy Commission

The project team then merged the data from these AV choice experiments with the data for estimating the vehicle choice experiments described in the previous section to estimate a joint model based on both data sources. Based on the result of this estimation, RSG does not recommend that the output of the autonomous vehicle DCE be used to forecast autonomous vehicle demand for two reasons.

First, the data gathered in the autonomous vehicle DCE, despite including only price and level of autonomy, demonstrated a higher level of variance than the data gathered in the vehicle type DCE. This high degree of variance suggests that respondents were inconsistent in their preferences for autonomous vehicles. It is possible that respondents had a difficult time imagining many of the vehicles in the experiment existing with options for, especially, Level 4 or Level 5 autonomy. Moreover, as the previous chapter demonstrated, respondents were generally opposed to purchasing AVs and wary of the technology. Because personally owned AVs are not available for purchase, many respondents likely struggled to see how the technology may or may not be valuable to them.

Second, the point estimates for the effect of each level of autonomy on household utility were predominately negative, though not statistically significant at conventional levels. This finding means that respondents generally did not differentiate between different levels of autonomy but were, on average, not willing to pay for increasing levels of autonomy, and it suggests that many respondents would have to be paid to accept increasing levels of vehicle autonomy. Again, this can be explained by respondents' general lack of knowledge about AVs and reluctance to purchase vehicles with autonomous technology.

Appendix J of this report (Volume 2) includes the specification of a model based only on data from the AV DCE, a model that is jointly estimated on data from the AV DCE and data from the vehicle type DCE. Both specifications indicate general inconsistency among respondents' preferences for AVs. However, in an additional specification of the joint model, the project team finds that when the reference vehicle in the AV DCE was a BEV, the estimated effect of increasing levels of autonomy on respondents' utility was positive, and statistically significant for Level 5 autonomy. This finding suggests that among the subset of respondents who say they would purchase a BEV would also be interested in AV technologies for BEVs.

Residential Vehicle Transaction and Replacement Model

The vehicle transaction and replacement model was estimated with data from the RP survey. The RP survey asked respondents about existing vehicles in their households and reported their expected replacement time frames for each. The replacement time frames, along with other household and vehicle characteristics, provide the basis for the dataset used to estimate this model.

The model considered only one transaction within the next year; multiple transactions within the next year were not included nor were transactions planned beyond the next year. That is, if a household expected to replace more than one vehicle within the next year, then only the first vehicle reported was coded as replaced. A maximum of three vehicles were considered for each household. If a household reported more than three vehicles, then the soonest three vehicles reported to be replaced were selected.

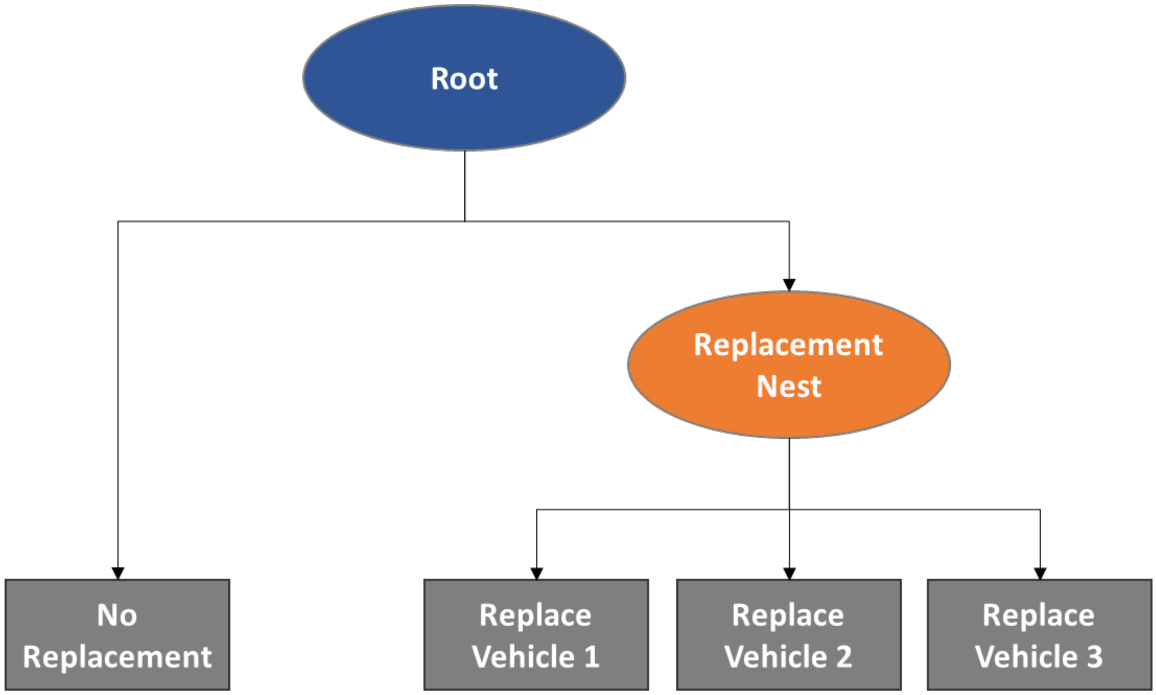
Residential Vehicle Transaction and Replacement Model Specification

The vehicle transaction and replacement model was estimated as a nested logit model with four alternatives:

1. No replacement
2. Replacement of vehicle 1
3. Replacement of vehicle 2 (if applicable)
4. Replacement of vehicle 3 (if applicable)

Alternatives two through four were grouped into a single replacement nest, while the no-replacement alternative stood alone in a separate nest. **Figure 54** shows the nested model structure. The structure of the nested logit model does not imply a sequential decision-making process; rather, it implies that the vehicle replacement alternatives are closer substitutes for each other than the no-replacement alternative.

Figure 54: Vehicle Transaction and Replacement Nested Logit Model Structure



Source: 2024 California Vehicle Survey, California Energy Commission

One alternative-specific constant applies to the no-replacement alternative. All other variables apply to the three vehicle replacement alternatives. Household-specific variables include household size, number of full-time equivalent workers, annual household income, and geography. The household size variable used in the model was a dummy variable equal to one for households with four or more persons. The number of full-time equivalent workers is calculated as the sum of full-time workers and one half the sum of part-time workers. The annual household income variable is separated into three categories. The first category includes all incomes below $35,000 annually and is the baseline category in the models.

The second category includes incomes between $35,000 and $99,999, and the third category includes incomes of at least $100,000. The values for these income categories were selected after running a model with dummy variables for each of the 10 income categories in the survey and identifying at what levels the parameter estimates began to change. These trichotomized variables perform much better than the log transformed income variable that has been used in previous versions of the CVS. The model also includes a dummy variable for self-reported geography collected in the CVS. Respondents that described their home location as "in a city center, central district, or downtown" were coded as urban. This is a new variable to the model, and it is highly significant in all specifications and improves the overall performance of the model.

One vehicle-specific variable was included in the final model: the age of the vehicle. The age of the vehicle is measured as 2024 minus the model year of the vehicle. These values were then transformed into four dummy variables for the following age categories:

- Vehicles up to one year old
- Vehicles between 2 and 7 years old
- Vehicles between 8 and 15 years old

- Vehicles more than 15 years old

These dummy variables performed better in the model than the log transformed age variable that has been used in the past. The cut points for these categories were determined similar to the process for the income categories. A model was run using every vehicle age as a dummy variable. In this model, significant differences were observed between vehicles that were one and two years old, seven and eight years old, and 15 and 16 years old.

The vehicle transaction and replacement model was estimated on the entire survey sample and on samples from each of the six regions in California (though due to limitations in the dependent variable, only regional models for San Francisco, Los Angeles, Sacramento and the Central Valley successfully converged). Dummy variables were used for five of the six regions defined in **Table 121** (with Rest of the State as the reference region). Results for the estimation without the regional variables are presented in the following section. Results with these regional variables are presented in Appendix J. This section also includes a model specification that matches the previous iterations of the CVS and discusses the process of deriving the specification presented below.

Residential Vehicle Transaction and Replacement Model Coefficient Estimates

Table 127 presents the estimates from a model that replicates past iterations of the transaction and replacement choice model and **Table 128** presents the model fit statistics. The models are estimated using top-down normalization in the modeling software, where the upper-level scale parameters are set to unity.

Table 127: Residential Vehicle Transaction and Replacement Choice (Replica)

Parameter	Variable	Description	Units	Coef.	T-Stat
α_1	No Replacement Constant	No Replacement Alternative Specific Constant	-	2.33	2.60
β_1	Vehicle Age (natural log)	2024-vehicle model year	Age	0.03	0.99
β_2	Large Household (>=4)	Households with 4 or more people	0, 1	0.50	3.80
β_3	Full Time Employees	Number of full-time employees	Persons	0.06	0.91
β_4	Income (natural log)	Natural log of annual household income	$	-0.02	-0.27
θ_{rep}	Replacement Nest	Nest Coefficient	-	0.10	-8.74*

Source: 2024 California Vehicle Survey, California Energy Commission

*The hypothesis test for the replacement nest coefficient is against the null hypothesis that the coefficient is equal to 1.

Table 128: Residential Vehicle Transaction and Replacement Model Fit Statistics

Fit Statistics	Value
Number of Observations	3,757
Initial Log-Likelihood	-3,777
Final Log-Likelihood	-1,372
Adjusted Rho-Square	0.64

Source: 2024 California Vehicle Survey, California Energy Commission

The dependent variable in this model is the choice between the four alternatives described previously. In a nested logit model, the probability of choosing an alternative is given by a product of the individual choice probabilities for each level in the nest structure. In this case, the probability of a household replacing one of their existing vehicles (e.g., vehicle *i*) within the next year is given by the probability that the household replaces any vehicle multiplied by the probability that the vehicle replaced is vehicle *i*:

$$P(i) = P(replacement) * P(vehicle_i)$$

Within-nest probabilities are given by the following equation:

$$P(vehicle_i) = \frac{e^{\frac{U_i}{\theta_{rep}}}}{\sum_j e^{\frac{U_j}{\theta_{rep}}}}$$

Where:

$U_j = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4$
θ_{rep} = Replacement nest coefficient
X_1 = The age of the vehicle under consideration (natural log)
X_2 = A dummy variable that equals 1 when a household has 4 or more people, else 0.
X_3 = The number of full-time employees in a household
X_4 = The annual household income of a household (natural log)

The nest probability is given by the following equation:

$$P(replacement) = \frac{e^{\theta_{rep}\, IV_{rep}}}{e^{\theta_{rep}\, IV_{rep}} + e^{\alpha_1}}$$

Where:

θ_{rep} = Nest coefficient

IV_{rep} = Inclusive value term = $LN(\sum_j e^{\frac{U_j}{\theta_{rep}}})$

α_1 = No-replacement constant

The inclusive value term, also referred to as the logsum, of the vehicle replacement nest represents the expected gain from choosing an alternative in the replacement nest.

Because the replica model seemed to be a poor fit compared to the 2019 iteration of the CVS, **Table 129** shows the coefficient estimates for an alternative specification of the vehicle transaction and replacement model with vehicle age and income included as dummy variables. **Table 130** shows the model fit statistics for this model.

Table 129: Residential Vehicle Transaction and Replacement Choice Coefficients, Full Specification

Parameter	Variable	Description	Unit	Coef.	T-Stat
α1	No Replacement Constant	No Replacement Alternative Specific Constant	-	2.89	8.30
	Vehicle Age Category 1	Vehicles up to 1 year old	0, 1	-	-
β1	Vehicle Age Category 2	Vehicles between 2 and 7 years old	0, 1	0.341	1.32
β2	Vehicle Age Category 3	Vehicles between 8 and 15 years old	0, 1	0.410	1.55
β3	Vehicle Age Category 4	Vehicles older than 15 years	0, 1	0.479	1.64
	Household Income Category 1	Annual household incomes less than $35,000	0, 1	-	-
β4	Household Income Category 2	Annual household incomes between $35,000 and $99,999	0, 1	-0.363	-1.91
β5	Household Income Category 3	Annual household incomes at least $100,000	0, 1	-0.128	-0.641
β6	Large Household (4+ members)	Households with four or more people	0, 1	0.349	2.87
β7	Urban (dummy)	Respondent lives in a city center	0, 1	.940	7.47
θrep	Replacement Nest	Nest Coefficient	-	0.323	-5.43*
*The hypothesis test for the replacement nest coefficient is against the null hypothesis that the coefficient is equal to 1.					

Source: 2024 California Vehicle Survey, California Energy Commission

Table 130: Residential Vehicle Transaction and Replacement Choice Model Fit Statistics, Full Specification

Fit Statistics	Value
Number of Observations	3,757
Initial Log-Likelihood	-3776.7
Final Log-Likelihood	-1346.29
Adjusted Rho-Square	0.641

Source: 2024 California Vehicle Survey, California Energy Commission

In this model the within-nest probabilities are given by the following equation:

$$P(vehicle_i) = \frac{e^{\frac{U_i}{\theta_{rep}}}}{\sum_j e^{\frac{U_j}{\theta_{rep}}}}$$

Where:

$U_i = \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7$

θ_{rep} = Replacement nest coefficient

X_1 = A dummy variable that equals 1 if a vehicle is between 2 and 7 years old, 0 otherwise

X_2 = A dummy variable that equals 1 if a vehicle is between 8 and 15 years old, 0 otherwise

X_3 = A dummy variable that equals 1 if a vehicle is more than 15 years old, 0 otherwise

X_4 = A dummy variable that equals 1 if a household's annual income is between $35,000 and $99,999, 0 otherwise

X_5 = A dummy variable that equals 1 if a household's annual income is at least $100,000, 0 otherwise

X_6 = A dummy variable that equals 1 if a household has 4 or more members, 0 otherwise

X_7 = A dummy variable that equals 1 if a household is located in a downtown or city center, 0 otherwise

In this alternative specification of the transaction and replacement model, both income and vehicle age approach statistical significance at conventional levels, but because these parameter estimates seem low compared to the past, the RSG team chose to build a model with an interaction between vehicle age and income. This model is premised on the idea that some older cars owned by lower-income households might be less likely to be replaced because the cost to replace these vehicles is a higher proportion of the household's income. The results from this model are reported in **Table 131**, and the summary statistics of the model are reported in **Table 132**.

Table 131: Residential Vehicle Transaction and Replacement Choice Model Estimates — Vehicle Age and Income Interactions

	Parameter	Description	Units	Coef.	T-Stat
α1	No Replacement Constant	_	-	2.949	10.655
	Vehicle Age Category 1	Vehicles up to 1 year old	0,1	0.000	NA
β1	Vehicle Age Category 2	Vehicles between 2 and 7 years old	0,1	0.419	2.201
β2	Vehicle Age Category 3	Vehicles between 8 and 15 years old	0,1	0.390	1.974
β3	Vehicle Age Category 4	Vehicles older than 15 years	0,1	0.507	2.269
	Household Income Category 1	Annual household incomes less than $35,000	0,1	0.000	NA
β4	Household Income Category 2	Annual household incomes between $35,000 and $99,999	0,1	-0.631	-2.729
β5	Household Income Category 3	Annual household incomes at least $100,000	0,1	-0.397	-1.708
	Vehicle Age Category 1 * Household Income Category 1		0,1	0.000	NA
	Vehicle Age Category 1 * Household Category 2		0,1	0.000	NA
	Vehicle Age Category 1 * Household Income Category 3		0,1	0.000	NA
	Vehicle Age Category 2 * Household Income Category 1		0,1	0.000	NA
β6	Vehicle Age Category 2 * Household Income Category 2		0,1	0.247	1.488
β7	Vehicle Age Category 2 * Household Income Category 3		0,1	0.282	1.840
	Vehicle Age Category 3 * Household Income Category 1		0,1	0.000	NA
β8	Vehicle Age Category 3 * Household Income Category 2		0,1	0.427	1.933
β9	Vehicle Age Category 3 * Household Income Category 3		0,1	0.656	2.760
	Vehicle Age Category 4 * Household Income Category 1		0,1	0.000	NA
β10	Vehicle Age Category 4 * Household Income Category 2		0,1	0.556	2.375
β11	Vehicle Age Category 4 * Household Income Category 3		0,1	0.480	1.799
β12	Large Household (4+ members)	Households with four or more people	0,1	0.367	3.015
β13	Urban (dummy)	Respondent lives in a city center	0,1	0.976	7.799
θrep	Replacement Nest	Nest Coefficient	-	0.426	-4.184*

***The hypothesis test for the replacement nest coefficient is against the null hypothesis that the coefficient is equal to 1.**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 132: Residential Vehicle Transaction and Replacement Choice Model Fit Statistics, Full Specification

Fit Statistics	Value
Number of Observations	3,757
Initial Log-Likelihood	-3776.7
Final Log-Likelihood	-1315.49
Adjusted Rho-Square	0.648

Source: 2024 California Vehicle Survey, California Energy Commission

In this model, the effect of vehicle age and income can be calculated for each group by adding the independent parameter estimates to the relevant interaction parameter. Based on these estimates, higher-income households are more likely to replace older vehicles than lower-income households.

Residential New-Used Vehicle Choice Model

When a vehicle transaction or replacement decision is made, the project team assumes that a household first chooses between purchasing a new or used vehicle and then chooses a specific vehicle from the set of available new or used vehicles.

Residential New-Used Vehicle Model Specification (Replica)

To support this model structure, a fractional multinomial logit model was estimated to predict whether the next vehicle purchased by a household will be new or used. In past iterations of the CVS, data from the survey questions that identify the respondents' reference vehicle for the vehicle type DCE were used to create the dependent variable for this model. The reference vehicle was either new or used, so a binary logit model could be estimated with these data. However, in the 2024 CVS, the vehicle type DCE was based on a consideration set of vehicles that, for most respondents, included more than one vehicle.

Because a respondent's consideration set can include new and used vehicles, the choice of new or used was no longer a binary choice in these data. Therefore, the project team opted to estimate a fractional multinomial logit model for which the outcome variable is the share of vehicles in the consideration set that are new. For example, if a respondent's consideration set included three new vehicles and one used vehicle, the share would be 75 percent.

The replica model specification is presented below, with **Table 133** showing the parameters and **Table 134** the fit statistics. An alternative model specification is presented after, with **Table 134** showing the parameters and **Table 135** the fit statistics. Additional alternative specifications of this model are presented in Appendix J.

Residential New-Used Model Coefficient Estimates

Following the specification used in 2019, the replica model is a function of household income (measured by the natural log of the midpoint in reported income categories), household size (measured by the natural log of the number of people in household), and a dummy variable that indicates whether the household has three or more vehicles. All coefficients apply to the new vehicle alternative.

Table 133: Residential New-Used Vehicle Choice Model

Parameter	Variable	Coef.	T-Stat
α_1	New vehicle constant	-8.49	-16.26
β_1	Household Income (Natural log)	0.75	16.36
β_2	Household Size (Natural log)	-0.06	-1.04
β_3	3 or more vehicle household dummy	-0.13	-1.66

Source: 2024 California Vehicle Survey, California Energy Commission

Table 134: Residential New-Used Vehicle Choice Model Fit Statistics

Fit Statistics	Value
Number of Observations	3,890
Null Log-Likelihood	-2,696
Final Log-Likelihood	-2,546
Adjusted Rho-Square	0.054

Source: 2024 California Vehicle Survey, California Energy Commission

The dependent variable was the proportion of choice among a new vehicles in a respondent's consideration set. The probability of selecting a new vehicle is given by the following equations:

$$P(new) = \frac{e^{U_{new}}}{e^{U_{new}} + 1}$$

Where:

$U_{new} = \alpha_1 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3$

X_1 = The natural log of a household's annual income ($)

X_2 = The natural log of the number of people in a household

X_3 = A dummy variable equal to 1 if the household has more than 2 vehicles, 0 otherwise

The income coefficient estimate was positive and significant, which suggested that higher-income households are more likely to purchase new vehicles. The negative coefficient for household size suggested that larger households are less likely to purchase a new vehicle. The negative estimate for the three or more vehicle dummy variable suggested that these households are less likely to purchase new vehicles. However, the latter two parameter estimates were not statistically significant at conventional levels.

Residential New-Used Alternative Model Specification

Because the replica model includes two model parameters that are not statistically significant at the 95 percent confidence level, the project team attempted to respecify the New-Used model by changing the way in which the household size and household vehicle variables enter the model. In this alternative specification, the household size variable is replaced by the number of employed persons in the household (both full-time and part-time) and the number of vehicles in the household enters the model, replacing the three or more vehicles household dummy variable.

Parameter estimates for this mode are displayed in **Table 135**, and fit statistics are displayed in **Table 136**.

Table 135: Residential New-Used Vehicle Choice Alternative Model

Parameter	Variable	Coef.	T-Stat
α_1	New vehicle constant	-8.67	-16.37
β_1	Household Income (Natural log)	0.79	16.63
β_2	Number of employed household member	-0.43	-5.18
β_3	Number of vehicles in the household	-0.08	-2.31

Source: 2024 California Vehicle Survey, California Energy Commission

Table 136: Residential New-Used Vehicle Choice Alternative Model Fit Statistics

Fit Statistics	Value
Number of Observations	3,890
Null Log-Likelihood	-2,696
Final Log-Likelihood	-2,534
Adjusted Rho-Square	0.059

Source: 2024 California Vehicle Survey, California Energy Commission

This alternative model performs significantly better than the replica model. Higher levels of income are associated with higher utility for new vehicles. Holding household income constant, more workers and more vehicles in a respondent's household are associated with lower utility for new vehicles.

Residential Vehicle Quantity Model

The probability of a household owning zero, one, two, or three or more vehicles is estimated by the vehicle quantity model. This model uses vehicle ownership data from the RP survey.

Vehicle ownership quantity alternatives are specified for categories of zero, one, two, and three or more household vehicles. The utility for the zero-vehicle alternative was fixed to zero.

Table 137 shows the results of a replica model with the same specification that was used in the 2019 CVS. In this model, each utility equation includes the same vector of covariates, but the parameter estimates are distinct for each vehicle ownership quantity alternatives. The covariates in this model are the natural log of the midpoint of the respondents' household income range, the natural log of the number of people in a household, and a count of the average weekly transit trips per person in the household. The value for annual household income used in the model was the midpoint value of the reported income range. For household incomes of $250,000 or more, the project team used a value of $275,000. The fit statistics for this model are listed in **Table 138**.

Table 137: Residential Vehicle Quantity Model (Replica)

Para meter	Variable	1 Veh Coef.	1 Veh T-Stat	2 Veh Coef.	2 Veh T-Stat	3+ Veh Coef.	3+ Veh T-Stat
α_i	Vehicle quantity constant	-5.51	-5.07	-14.04	-11.39	-19.02	-13.43
$\beta_{1,i}$	Natural log of household income ($)	0.76	7.50	1.42	12.59	1.67	13.23
$\beta_{2,i}$	Natural log of household size	0.41	1.50	2.05	7.26	3.31	11.08
$\beta_{3,i}$	Weekly transit trips per household member	-0.09	-4.17	-0.14	-4.75	-0.16	-4.44

Source: 2024 California Vehicle Survey, California Energy Commission

Table 138: Residential Vehicle Quantity Model Fit Statistics (Replica)

Fit Statistics	Value
Number of Observations	3,881
Null Log-Likelihood	-5,380
Final Log-Likelihood	-3,745
Adjusted Rho-Square	0.302

Source: 2024 California Vehicle Survey, California Energy Commission

The probability of owning zero, one, two, or three or more vehicles was assigned using the utility for each ownership level: i = 0, 1, 2, 3 for zero vehicles, one vehicle, two vehicles, and three or more vehicles, respectively:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_j}}$$

Where U_i is the modeled utility of ownership category i, given by the following equations:

$U_0 = 0.$

For i = 1, 2 or 3,

$U_i = \alpha_i + \beta_{1,i}X_1 + \beta_{2,i}X_2 + \beta_{3,i}X_3$

Where

X_1 = The natural log of the respondent’s annual household income ($)

X_2 = The natural log of the number of members in the respondent's household

X_3 = The number of transit trips taken each week per person in the respondent's household

In refining the vehicle quantity model, RSG attempted to build a model that estimated distinct utility equations for each ownership alternative. This alternative specification is discussed below.

The alternative vehicle quantity model is a function of a vector of household-level variables. Household income, the number of licensed drivers in the household, the number of employed members per household member, and population density are included in the utility equations of all vehicle ownership quantity alternatives with distinct coefficients. Household income is measured by the natural log of the midpoint of reported income categories. The population density is calculated at the ZIP code level using the 2019–2023 American Communities Survey in units of 10,000 people per square miles.

Four additional variables are included with some constraints to reduce model complexity and statistically insignificant coefficients. The number of children under 16 is included only for two or three or more vehicle alternatives because of the lack of statistical significance on the one vehicle alternative. The average weekly transit trips per household member is included for all alternatives, but the coefficient for the two vehicles alternative is constrained to be equal to that for the three or more vehicles alternative. Besides population density, two additional built environment variables are included: the rural dummy variable is included only for the three or more vehicles alternative, and the downtown dummy variable is included for both two and three or more vehicle alternatives with the constraint that they have the same coefficient.

Full model results are shown in **Table 139**, and model fit statistics are reported in **Table 140**.

Table 139: Residential Vehicle Quantity Model

Parameter	Variable	1 Veh Coef.	1 Veh T-Stat	2 Veh Coef.	2 Veh T-Stat.	3+ Veh Coef.	3+ Veh T-Stat
α_i	Vehicle ownership constant	-5.534	-4.79	-14.619	-11.01	-22.191	-13.58
β_1	Natural log of household income ($)	0.653	5.80	1.282	10.25	1.644	11.28
β_2	Number of licensed drivers	1.305	3.70	2.658	7.10	3.801	9.72
β_3	Proportion of household members who are employed	0.803	2.98	0.559	1.99	0.681	2.23
β_4	Number of children under 16	--	--	0.318	4.98	0.370	4.86
β_5	Weekly transit trips per household member	-0.088	-3.31	-0.103*	-3.32	-0.103*	-3.32
β_6	Population density (10k people per square mile)	-0.556	-5.76	-0.887	-7.70	-1.215	-8.29
β_7	Rural dummy	--	--	--	--	0.861	4.36
β_8	Downtown dummy	--	--	-0.491*	-4.02	-0.491*	-4.02

***These parameter estimates are shared across utility equations**

Source: 2024 California Vehicle Survey, California Energy Commission

Table 140: Residential Vehicle Quantity Model Fit Statistics

Fit Statistics	Value
Number of Observations	3,881
Null Log-Likelihood	-5,380
Final Log-Likelihood	-3,427
Adjusted Rho-Square	0.359

Source: 2024 California Vehicle Survey, California Energy Commission

The probability of owning zero, one, two, or three or more vehicles was assigned using the utility for each ownership level: i = 0, 1, 2, 3 for zero vehicles, one vehicle, two vehicles, and three or more vehicles, respectively:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_i}}$$

Where U_i is the modeled utility of ownership category i, given by the following equations:

$U_0 = 0$

$U_1 = \alpha_1 + \beta_{1,1}X_1 + \beta_{2,1}X_2 + \beta_{3,1}X_3 + \beta_{5,1}X_5 + \beta_{6,1}X_6$

$U_2 = \alpha_2 + \beta_{1,2}X_1 + \beta_{2,2}X_2 + \beta_{3,2}X_3 + \beta_{4,2}X_4 + \beta_{5,2}X_5 + \beta_{6,2}X_6 + \beta_{8,2}X_8$

$U_3 = \alpha_3 + + \beta_{1,3}X_1 + \beta_{2,3}X_2 + \beta_{3,3}X_3 + \beta_{4,3}X_4 + \beta_{5,2}X_5 + \beta_{6,3}X_6 + \beta_{7,3}X_7 + \beta_{8,2}X_8$

Where:

α_1 = The alternative specific constant for the 1 vehicle alternative

α_2 = The alternative specific constant for the 2 vehicles alternative

α_3 = The alternative specific constant for the 3+ vehicles alternative

X_1 = The natural log of respondents' annual household income ($)

X_2 = The number of licensed drivers in the respondent's household

X_3 = The proportion of household members who are employed

X_4 = The number of children (under 16) in the respondent's household

X_5 = The number of weekly transit trips for all members of the respondent's household

X_6 = The population density in the respondent's ZIP code (10,000 people per square mile)

X_7 = A dummy variable indicating that the respondent lives in a rural area, 0 otherwise

X_8 = A dummy variable indicating that the respondent lives in a downtown area, 0 otherwise

In this model, increasing income, number of licensed drivers, number of children under 16, and being in a rural environment are positively correlated with increasing quantities of household vehicle ownership. Increasing population density, weekly transit trips per household member, and being in a downtown environment are associated with decreasing quantities of household vehicle ownership.

Residential Vehicle Miles Traveled Model

The Vehicle Miles Traveled (VMT) model was estimated at an individual vehicle level based on respondent's reported annual VMT from the previous year for each household vehicle. Outlier annual VMT values, defined as the top two and bottom two percentiles, were removed. This removal resulted in 7,011 annual VMT values for modeling, ranging from 45 miles to 44,434 miles. Separate models were fitted to the household ownership quantity categories of one, two, and three or more vehicles. Several alternative specifications of this model are reported here and in the appendix.

First, the VMT model was estimated as a log-linear regression with the dependent variable specified as the natural log of VMT. This model is a function of both vehicle-level characteristics and household-level characteristics. Vehicle-level characteristics include:

- Age of the vehicle.
- A dummy variable indicating that the vehicle is a car (as opposed to crossover, SUV, van, and pickup).
- A dummy variable indicating that the vehicle is a ZEV (PHEV, BEV, FCV, or PFCV).
- A dummy variable indicating that the vehicle is a hybrid.

The household-level characteristics include:

- The number of licensed drivers in the household.
- The number of employees per household member.
- Household annual income (mid-point of income range, $, natural log).
- Average household weekly one-way transit trips per capita.
- A dummy variable indicating that the household owns four or more (only included in the three or more vehicle model).
- Population density of the household residence location (at the zip code level, in units of 10,000 people per square miles, data from 2019–2023 ACS).
- A dummy variable indicating that the household resides in a city center or downtown area.

Table 141 presents the estimation results of the VMT models for the three-category vehicle ownership segmentations and **Table 142** presents the model fit statistics.

Table 141: Residential VMT Model

Parameter	Variable	Units	1 Veh Coef.	1 Veh T-Stat	2 Veh Coef.	2 Veh T-Stat	3+ Veh Coef.	3+ Veh T-Stat
α_1	Intercept	--	8.329	19.44	7.748	23.85	8.124	18.96
β_1	Number of Licensed Drivers in HH	Persons	0.033	0.76	0.211	6.53	0.175	7.84
β_2	Proportion of Household Members who are Employed	Persons/ Persons	0.288	4.33	0.292	5.80	0.404	5.95
β_3	Annual Household Income	Ln ($)	0.036	0.97	0.052	1.91	0.030	0.86
β_4	Weekly Transit Trips per Household Member	Trips/Persons	0.004	0.45	-0.036	-5.07	-0.030	-3.62
β_5	Vehicle Age	Years	-0.003	-0.24	-0.005	-0.94	-0.036	-6.84
β_6	Vehicle Age Squared	Years^2	-0.0004	-1.06	-0.001	-5.07	-0.0002	-1.89
β_7	Vehicle Type, Car Indicator	0, 1	-0.067	-1.16	-0.053	-1.44	-0.151	-3.58
β_8	Fuel Type, ZEV Indicator	0, 1	-0.048	-0.57	0.146	2.88	0.134	2.08
β_9	Fuel Type, Hybrid indicator	0, 1	0.028	0.29	0.051	0.78	0.188	2.27
β_{10}	Population Density	10k people per sq. miles	-0.134	-3.34	-0.130	-4.05	-0.189	-4.31
β_{11}	Downtown Indicator	0, 1	-0.190	-2.58	-0.261	-4.72	-0.350	-4.39
β_{12}	More than 3 vehicles	0, 1					-0.122	-2.68

Source: 2024 California Vehicle Survey, California Energy Commission

Table 142: Residential VMT Model Fit Statistics

Fit Statistics	1 Vehicle	2 Vehicles	3+ Vehicles
Number of Observations (vehicles)	1,318	3,085	2,608
Adjusted R-Squared	0.04	0.13	0.25

Source: 2024 California Vehicle Survey, California Energy Commission

The dependent variable for this model is the natural log of respondents' self-reported VMT at the vehicle level, and the full equation of the model is given by:

$$Ln\ (VMT) = \alpha_1 + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \beta_4 X_4 + \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_9 X_9 + \beta_{10} X_{10} + \beta_{11} X_{11} + \beta_{12} X_{12}$$

α_1 = Intercept

X_1 = The number of licensed drivers in a household

X_2 = The proportion of household members who are employed

X_3 = The natural log of household's annual income ($)

X_4 = The average number of transit trips per household member

X_5 = The age of the vehicle

X_6 = The age of the vehicle squared

X_7 = A dummy variable equal to 1 if the vehicle is a car, 0 otherwise

X_8 = A dummy variable equal to 1 if the vehicle is a ZEV, 0 otherwise

X_9 = A dummy variable equal to 1 if the vehicle is a hybrid, 0 otherwise

X_{10} = Population density (10,000 per square mile)

X_{11} = A dummy variable equal to 1 if the household lives in a downtown or city center area, 0 otherwise

X_{12} = A dummy variable equal to 1 if the household owns more than 3 vehicles, 0 otherwise (this variable was only included in the pooled model and the model for households with 3 or more vehicles)

The household size and fuel cost ($/mile) variables, used in the in the 2019 CVS, were found to not be statistically significant and, therefore, excluded from the 2024 VMT models. Instead of household size, the model includes the number of licensed drivers and the number of employees per household member.

Based on these models, higher numbers of licensed drivers and proportion of household members who are employed are associated with higher per-vehicle VMT. Conversely, higher transit use, higher vehicle age, higher population density, being a car (vehicle type), the household being in downtown environment, and the household owning three or more vehicles are associated with lower per-vehicle VMT. Once other variables are accounted for, annual household income is not a statistically significant variable for estimating VMT. Lastly, ZEV vehicles are associated with higher VMT for two and three or more car households, and hybrid vehicles are associated with higher VMT for three or more car households.

Residential Vehicle Miles Traveled Model — Alternate Specification with Random Effects

Table 143 shows the results of a model identical to those reported above but that also includes random intercept variance (random effects) at the household level. Because one-vehicle households do not vary at the vehicle level, random effects cannot be added to the model for this subset, so the table includes a model estimated with the entire sample of vehicles. **Table 144** shows the fit statistics for this model specification.

Table 143: Residential VMT Model — Alternate Specification with Random Effects

Variable	Units	Pooled Coef.	Pooled T-Stat	2 Veh Coef.	2 Veh Coef.	3+ Veh T-Stat	3+ Veh Coef.
Intercept	--	9.144	37.56	8.212	21.28	8.555	14.38
Number of Licensed Drivers in HH	Persons	0.086	4.45	0.201	5.08	0.168	5.10
Proportion of household members who are employed	Persons/Persons	0.337	8.16	0.290	4.69	0.396	4.07
Annual Household Income	ln ($)	-0.035	-1.64	0.022	0.67	-0.0003	-0.01
Weekly Transit Trips per Household Member	Trips/Person	-0.020	-3.55	-0.036	-4.21	-0.027	-2.37
Vehicle Age	Years	-0.027	-8.63	-0.017	-3.30	-0.043	-9.19
Vehicle Age Squared	Years^2	-0.0004	-6.38	-0.001	-4.38	-0.0001	-1.62
Vehicle Type, Car Indicator	0, 1	-0.054	-2.41	-0.071	-2.23	-0.073	-1.98
Fuel Type, ZEV Indicator	0, 1	0.129	3.78	0.176	3.77	0.150	2.52
Fuel Type, Hybrid indicator	0, 1	0.113	2.69	0.109	1.85	0.176	2.44
Population Density	10k people per square mile	-0.142	-5.53	-0.138	-3.53	-0.227	-3.62
Downtown Indicator	0, 1	-0.286	-6.22	-0.283	-4.19	-0.439	-3.86
More than 3 vehicles	0, 1	-0.167	-2.89	--	--	-0.088	-1.31

Source: 2024 California Vehicle Survey, California Energy Commission

Table 144: Residential VMT Model Fit Statistics — Alternate Specification

Fit Statistics	Pooled Sample	2 Vehicles	3+ Vehicles
Number of Observations (vehicles)	7,011	3,085	2,608
Number of fixed Parameters	14	13	14
Adjusted Pseudo R-Squared	0.1732	0.1449	0.2787
Random Standard Deviation of the intercept	0.701	0.715	0.704

Source: 2024 California Vehicle Survey, California Energy Commission

The random intercepts model outperformed the base model. However, the income parameter remains insignificant at conventional levels.

Commercial Vehicle Choice Model

Data from the commercial fleet SP survey were combined with fleet information from the RP survey to form a dataset for the commercial vehicle choice model. The final dataset used to fit the commercial vehicle choice model contained 16,960 observations from 2,120 respondents.

In the stated preference portion of the survey, respondents completed eight vehicle choice experiments. In a similar fashion to the residential survey, each stated preference experiment presented respondents with four hypothetical vehicles described by a set of attributes. The new or used vehicle the respondent planned to purchase next for their establishment based on their responses in the RP survey — or the reference vehicle — was always presented as one of the vehicle alternatives. The order of the alternatives was randomized from one experiment to the next to minimize potential order bias. As a result, the reference vehicle could be presented as Vehicle A, B, C, or D in any given experiment.

The vehicle attributes presented for the nonreference alternative varied according to the experimental design. Respondents were asked to select the vehicle they would most likely purchase based on the attribute levels presented for each of the four alternatives. Detailed information about the alternatives, attributes, levels, and experimental design used in the SP survey can be found in Chapter 3.

Commercial Vehicle Type Choice Model Specification

The project team modeled the choice among the four vehicle alternatives using an MNL model form. Coefficients of this logit model form were estimated for many utility function specifications. All the specifications included the vehicle attributes that were varied in the SP experiments, business or industry characteristics, and constants for different vehicle types, vehicle sizes, and fuel options. The attributes and levels shown in the commercial vehicle survey were identical to those in the residential SP survey and are discussed above in the residential vehicle choice description. Many of the same specification tests for vehicle type — fuel type interactions that were conducted for the residential vehicle choice model were also conducted here.

Additional specification tests specific to the commercial model included interaction terms between the industry group and the vehicle type or fuel type, using the station availability time instead of the station location, a logarithmic price term, and fleet size. Additionally, specification tests included inertia terms representing the tendency for a company to prefer vehicles of the same vehicle or fuel type as their current fleet.

Constants

Several reference vehicle and alternative vehicle constants were tested in the vehicle choice utility specification to remove potential bias from the coefficient estimates.

The project team included a reference vehicle constant on the choice option that matched the specifications of the respondent's next vehicle purchase, and this constant was fixed at zero. Constants were also included on the additional alternatives to capture any unobserved utility compared to the reference vehicle. These constants were included to remove potential bias from the coefficient estimates.

Industry Groups

The primary commercial demographic variable examined was industry type. There are, in many cases, differences in preferences among industry types for attributes such as vehicle type and fuel type. Several different specifications were tested to account for this taste heterogeneity among industries, including using industry interaction terms with various variables and estimating separate model segments for several different groups of industries.

Table 145 lists the industry classifications based on the NAICS sector. The detailed NAICS classifications were reassigned to three broad industry groups. **Table 146** summarizes the number of companies and available choice sets from each industry group.

Table 145: Industry Classifications

Industry Group	Industries Included
Industry Group 1	Agriculture, Forestry, Fishing, and Hunting
	Mining, Quarrying, and Oil and Gas Extraction
	Utilities (i.e., Electric, Gas, Water)
	Construction
	Manufacturing
Industry Group 2	Wholesale Trade
	Retail Trade
	Transportation and Warehousing
Industry Group 3	Information (i.e., Communications, Information Services, Publishers, Telecommunications)
	Finance and Insurance
	Real Estate and Rental and Leasing
	Professional, Scientific, and Technical Services (i.e., Lawyers, Engineering, Marketing)
	Management of Companies and Enterprises
	Administrative and Support and Waste Management and Remediation Services
	Educational Services (i.e., Schools, Colleges, Universities)
	Health Care and Social Assistance
	Arts, Entertainment, and Recreation
	Accommodation and Food Services
	Public Administration
	Repair Service
	A/O Professional, Scientific, and Technical Services Mentions

Source: 2024 California Vehicle Survey, California Energy Commission

Table 146: Industry Distribution of the Sample

Industry Group	Number of Companies	Number of Observations (choice sets)
Industry Group 1	739	5,912
Industry Group 2	216	1,728
Industry Group 3	1165	9,320
Total	**2,120**	**16,960**

Source: 2024 California Vehicle Survey, California Energy Commission

Industry Group and Vehicle Body Type Interaction

This term represents the interaction between the industry group and the vehicle body type. Industry Group 1 was treated as the reference case. The vehicles were grouped into the following body type categories:

- Car (the base)
- SUV
- Van
- Pick-up

The coefficients for the interactions with Industry Group 1 or with "car" type were constrained to zero.

Industry Group and Fuel Group Interaction

This term represents the interaction between the industry group and the vehicle fuel group. Industry Group 1 was treated as the reference case. The fuel types were grouped into the following categories:

- Non-ZEV (the baseline)
- ZEV

The coefficients for the interactions with Industry Group 1 or with non-ZEV fuel group was constrained to zero.

The model with vehicle group and fuel group interactions is presented in Appendix J.

Number of Vehicles in Fleet

An additional set of variables was included in the commercial model to capture the likelihood of a respondent choosing vehicles of a similar body type to the vehicles in the existing fleet. Vehicles were grouped into four types: cars, SUVs, pickup trucks, and vans:

- Number of cars in fleet: Subcompact car, compact car, midsize car, large car, sports car
- Number of SUVs in fleet: Small crossover, midsize crossover, small SUV, midsize SUV, large SUV
- Number of trucks in fleet: Standard pick-up truck, full-size pick-up truck
- Number of vans in fleet: Small van, full-size van

The number of fleet vehicles in each of these groups was included as a variable in the model. The interpretation of this is that respondents with a large number of one type of vehicle in their existing fleets are more likely to replace or add a vehicle of the same type in the future.

The model with fleet size interactions is presented in Appendix J.

Vehicle Price

Vehicle price is log transformed in the commercial model to reflect decreasing marginal sensitivity to cost as vehicle price increases.

Commercial Vehicle Type Choice Model

The commercial vehicle choice model coefficient estimates are presented in Table 147, and model fit statistics are presented in Table 148.

Table 147: Commercial Vehicle Type Choice Model

	Variable	Units	Coef.	T-Stat
α1	Reference vehicle (from consideration set)	-	0.000	NA
α2	First non-reference vehicle	-	-1.200	-42.009
α3	Second non-reference vehicle	-	-1.541	-45.017
α4	Third non-reference vehicle	-	-1.920	-48.861
β1,1	Subcompact Car	0,1	0.000	NA
β1,2	Compact Car	0,1	0.164	1.576
β1,3	Midsize Car	0,1	0.595	5.948
β1,4	Large Car	0,1	0.670	5.991
β1,5	Sports Car	0,1	0.449	3.668
β1,6	Subcompact Crossover	0,1	0.258	2.376
β1,7	Compact Crossover	0,1	0.553	5.200
β1,8	Midsize Crossover/SUV	0,1	1.096	10.814
β1,9	Large SUV	0,1	1.141	10.326
β1,10	Small Van	0,1	1.029	9.656
β1,11	Full-size/large Van	0,1	1.442	13.836
β1,12	Small Pickup Truck	0,1	1.213	12.075
β1,13	Full-size/large Pickup Truck	0,1	1.962	18.419
β2,1	Gasoline only	0,1	0.000	NA
β2,2	Gas HEV	0,1	-0.279	-5.805
β2,3	PHEV	0,1	-1.217	-6.522
β2,4	Diesel	0,1	-0.279	-2.698
β2,5	BEV	0,1	-0.519	-2.180
β2,6	FCV	0,1	-0.579	-2.759
β2,7	PFCV	0,1	-1.323	-4.774
β3,1	Standard	0,1	0.000	NA
β3,2	Premium	0,1	0.441	7.288
β4,1	New	0,1	0.000	NA
β4,2	Used (3 Years Old)	0,1	-0.404	-8.834
β4,3	Used (6 Years Old)	0,1	-0.657	-9.329
β5	Vehicle price	ln($1000)	-0.536	-9.268
β6	Total Range	ln(Miles)	0.180	3.770

	Variable	Units	Coef.	T-Stat
β7	Share of stations with diesel	%	0.151	0.830
β8	Distance to hydrogen station	Miles	-0.007	-2.219
β9,1	Distance to Level 2 charger	Minutes	-0.003	-0.681
β9,2	Distance to Fast charger	Minutes	0.003	0.828
β9,3	Wait time for Fast charger	Minutes	-0.003	-1.729
β10,1	No home charging	0,1	0.000	NA
β10,2	Home charging	0,1	0.737	5.632
β11,1	No work charging	0,1	0.000	NA
β11,2	Work charging: Level 2	0,1	0.047	0.851
β11,3	Work charging: Fast	0,1	0.138	2.352
β12	MPG or MPGe	Miles per gallon	0.004	3.054
β13	Fuel cost per 100 miles	ln($1000)	-0.308	-5.864
β14,1	Level 2 charge time to go 10 miles	Minutes	0.003	0.906
β14,2	Level 2 charge time 10% to 80% charge	Hours	-0.006	-0.764
β14,3	Fast charge time 10% to 80% charge	Minutes	-0.003	-1.831
β15,1	No purchase incentive	0,1	0.000	NA
β15,2	HOV lane incentive	0,1	0.069	1.008
β15,3	Tax incentive	$1000s	0.033	3.874
β15,4	Rebate incentive	$1000s	0.025	2.179
β16	Annual maintenance cost	ln($1000s)	-0.334	-5.759
β17	0-60 MPH acceleration	Seconds	-0.016	-1.788

Source: 2024 California Vehicle Survey, California Energy Commission

Table 148: Commercial Vehicle Type Choice Model Fit Statistics

Fit Statistics	Value
Number of Observations	16960
Number of Individuals	2120
Null Log-Likelihood	-18086.62
Final Log-Likelihood	-15464.76
Adjusted Rho-Square	0.404

Source: 2024 California Vehicle Survey, California Energy Commission

Based on the model specification and coefficient values, the forecasted probability of a company selecting vehicle *i,* with vehicle class *v*, fuel type *f*, age *a*, and prestige *p* is given by the following formula:

$$P(i) = \frac{e^{U_i}}{\sum_j e^{U_j}}$$

Where U_i is the modeled utility of vehicle i, given by the following equation:

$$U_i = \alpha_i + \sum_{v=1}^{13} \beta_{1,v} X_{1,v} + \sum_{f=1}^{7} \beta_{2,f} X_{2,f} + \sum_{p=1}^{2} \beta_{3,p} X_{3,p} + \sum_{a=1}^{3} \beta_{4,a} X_{4,a} +$$

$+ \beta_5 X_5 + \beta_6 X_6 + \beta_7 X_7 + \beta_8 X_8 + \beta_{9,1} X_{9,1} + \beta_{9,2} X_{9,2} + \beta_{9,3} X_{9,3} + \beta_{10,1} X_{10,1} + \beta_{10,2} X_{10,2} + \beta_{11,1} X_{11,1} + \beta_{11,2} X_{11,2} + \beta_{11,3} X_{11,3} + \beta_{12} X_{12} + \beta_{13} X_{13} + \beta_{14,1} X_{14,1} + \beta_{14,2} X_{14,2} + \beta_{14,3} X_{14,3} + \beta_{15,1} X_{15,1} + \beta_{15,2} X_{15,2} + \beta_{15,3} X_{15,3} + \beta_{15,4} X_{15,4} + \beta_{16} X_{16} + \beta_{17} X_{17}$

The terms in this equation are given by:

α_i = A constant for each vehicle alternative (reference and non-reference) in the DCE

$X_{1,v}$ = Array of dummy variables equal to 1 when vehicle type = *v*, otherwise 0

$X_{2,f}$ = Array of dummy variables equal to 1 when fuel type = *f*, otherwise 0

$X_{3,p}$ = Dummy variable equal to 1 when prestige = *p*, otherwise 0; available values for *p* are "standard" and "premium."

$X_{4,a}$ = Array of dummy variables equal to 1 when vehicle age = a, otherwise 0; available values for *a* are "new," "used (three years old)," and "used (six years old)."

X_5 = Purchase price of the vehicle ($1,000, natural log)

X_6 = Average range of the vehicle at 100% fueled (miles, natural log)

X_7 = Proportion of gas stations that have diesel fuel

X_8 = Distance to a hydrogen fuel station miles)

$X_{9,1}$ = Distance to a Level 2 charger (minutes)

$X_{9,2}$ = Distance to a Level 3 fast charger (minutes)

$X_{9,3}$ = Wait time for a Level 3 fast charger (minutes)

$X_{10,2}$ = A dummy variable that equals 1 if there is access to a home charger, 0 otherwise

$X_{11,2}$ = A dummy variable that equals 1 if a respondent has access to a Level 2 charger at work, 0 otherwise

$X_{11,3}$ = A dummy variable that equals 1 if a respondent has access to a Level 3 fast charger at work, 0 otherwise

X_{12} = The average MPG or MPGe for the vehicle (weighted 60 percent electric and 40 percent gas for PHEVs, and 60 percent electric and 40 percent hydrogen for PFCVs)

X_{13} =Fuel cost per 100 miles for the vehicle (weighted 60 percent electric and 40 percent gas for PHEVs, and 60 percent electric and 40 percent hydrogen for PFCVs) ($1,000)

$X_{14,1}$ = Time to charge the vehicle enough to drive 10 miles with a Level 2 charger (minutes)

$X_{14,2}$ = Time to charge the vehicle from 10 percent to 80 percent with a Level 2 charger (hours)

$X_{14,3}$ = Time to charge the vehicle from 10 percent to 80 percent with a Level 3 fast charger (minutes)

$X_{15,2}$ = A dummy variable that equals 1 if the vehicle qualifies for access to the HOV lanes, 0 otherwise

$X_{15,3}$ = The value of a tax incentive for the vehicle ($1,000)

$X_{15,4}$ = The value of a rebate incentive for the vehicle ($1,000)

X_{16} = Average annual maintenance costs for vehicle ($1,000, natural log)

X_{17} = Average time to accelerate from 0 to 60 MPH (seconds)

The denominator term is the sum of exponentiated utilities for all vehicles in the respondent's choice set, which includes all vehicle types and fuel types available for each model year.

In this base model, unlike in the residential model, large SUVs, large vans, and pick-up trucks were associated with the highest levels of utility for respondents. Furthermore, all alternative fuels were associated with lower levels of utility than gasoline vehicles.

Commercial Vehicle Choice Model Coefficient Estimates — ZEV Owners' Interaction

The project team estimated the commercial vehicle choice model separately to include an interaction term between fuel-type inertia and ZEV fuel types (BEV, PHEV, FCEV, and PFCEV) for respondents who indicated that they own a ZEV. The coefficients for the ZEV-Fuel-type interaction model are presented in **Table 149,** and the model fit statistics are presented in **Table 150**.

Table 149: Commercial ZEV Owner Vehicle Type Choice Model — ZEV Interaction

	Variable	Units	Coef.	T-Stat
α1	Reference vehicle (from consideration set)	-	0.000	NA
α2	First non-reference vehicle	-	-1.169	-40.891
α3	Second non-reference vehicle	-	-1.505	-43.990
α4	Third non-reference vehicle	-	-1.884	-47.803
β1,1	Subcompact Car	0,1	0.000	NA
β1,2	Compact Car	0,1	0.174	1.667
β1,3	Midsize Car	0,1	0.589	5.898
β1,4	Large Car	0,1	0.653	5.843
β1,5	Sports Car	0,1	0.458	3.740
β1,6	Subcompact Crossover	0,1	0.260	2.394
β1,7	Compact Crossover	0,1	0.550	5.171
β1,8	Midsize Crossover/SUV	0,1	1.100	10.861
β1,9	Large SUV	0,1	1.152	10.443
β1,10	Small Van	0,1	1.039	9.747
β1,11	Full-size/large Van	0,1	1.455	13.952
β1,12	Small Pickup Truck	0,1	1.218	12.125
β1,13	Full-size/large Pickup Truck	0,1	1.976	18.574
β2,1	Gasoline only	0,1	0.000	NA
β2,2	Gas HEV	0,1	-0.267	-5.537
β2,3	PHEV	0,1	-1.284	-6.774
β2,4	PHEV x (ZEV owner)	0,1	0.731	5.664
β2,5	Diesel	0,1	-0.263	-2.526
β2,6	BEV	0,1	-0.688	-2.840
β2,7	BEV x (ZEV owner)	0,1	1.192	9.963
β2,8	FCV	0,1	-0.641	-2.995
β2,9	FCV x (ZEV owner)	0,1	0.650	4.334

	Variable	Units	Coef.	T-Stat
β2,10	PFCV	0,1	-1.399	-4.980
β2,11	PFCV x (ZEV owner)	0,1	0.905	6.072
β3,1	Standard	0,1	0.000	NA
β3,2	Premium	0,1	0.443	7.266
β4,1	New	0,1	0.000	NA
β4,2	Used (3 Years Old)	0,1	-0.404	-8.834
β4,3	Used (6 Years Old)	0,1	-0.666	-9.427
β5	Vehicle price	ln($1000)	-0.547	-9.411
β6	Total Range	ln(Miles)	0.180	3.762
β7	Share of stations with diesel	%	0.180	0.979
β8	Distance to hydrogen station	Miles	-0.007	-2.156
β9,1	Distance to Level 2 charger	Minutes	-0.004	-0.863
β9,2	Distance to Fast charger	Minutes	0.004	0.942
β9,3	Wait time for Fast charger	Minutes	-0.004	-1.972
β10,1	No home charging	0,1	0.000	NA
β10,2	Home charging	0,1	-0.016	-0.106
β11,1	No work charging	0,1	0.000	NA
β11,2	Work charging: Level 2	0,1	0.038	0.664
β11,3	Work charging: Fast	0,1	0.130	2.168
β12	MPG or MPGe	Miles per gallon	0.004	3.102
β13	Fuel cost per 100 miles	ln($1000)	-0.312	-5.865
β14,1	Level 2 charge time to go 10 miles	Minutes	0.003	1.020
β14,2	Level 2 charge time 10% to 80% charge	Hours	-0.007	-0.809
β14,3	Fast charge time 10% to 80% charge	Minutes	-0.003	-1.818
β15,1	No purchase incentive	0,1	0.000	NA
β15,2	HOV lane incentive	0,1	0.066	0.961
β15,3	Tax incentive	$1000	0.035	3.991
β15,4	Rebate incentive	$1000	0.024	2.139
β16	Annual maintenance cost	ln($1000)	-0.339	-5.853
β17	0-60 MPH acceleration	Seconds	-0.015	-1.672

Source: 2024 California Vehicle Survey, California Energy Commission

Table 150: Commercial ZEV Owner Vehicle Type Choice Model Fit Statistics

Fit Statistics	Value
Number of Observations	16960
Number of Individuals	2120
Null Log-Likelihood	-18086.62
Final Log-Likelihood	-15365.69
Adjusted Rho-Square	0.3444

Source: 2024 California Vehicle Survey, California Energy Commission

The utility equations for the ZEV Owner model are identical to those described above in the Commercial Vehicle Choice model, but with the addition of interaction terms for ZEV owners and ZEV fuel types in the DCE.

As in the residential vehicle type choice model, ZEV owners' utility increases for all ZEV fuel types.

Commercial Vehicle Choice Model — Industry Group Specific

Finally, the commercial vehicle choice model was estimated separately to include parameter estimates on the interaction between industry group number and vehicle class, industry group and fuel type (aggregated to ZEV), and vehicle class and ownership patterns among firms. This model included the following additional parameter estimates:

- An interaction between Industry Group 2 and Industry Group 3 (Industry Group 1 was the baseline) and an array of vehicle body type dummy variables (car was the base body type).
- An interaction between industry group and a truncated array of fuel types (non-ZEV was the base fuel type).
- An interaction between a truncated array of vehicle classes and the proportion of vehicles of that class in a given fleet.

Table 151 lists the estimates for this model, and Table 152 shows the model fit statistics.

Table 151: Commercial Vehicle Choice Model by Industry Type

	Variable	Units	Coef.	T-Stat
α1	Reference vehicle (from consideration set)	-	0.000	NA
α2	First non-reference vehicle	-	-1.074	-37.44
α3	Second non-reference vehicle	-	-1.337	-38.54
α4	Third non-reference vehicle	-	-1.688	-42.25
β1,1	Subcompact Car	0,1	0.000	NA
β1,2	Compact Car	0,1	0.164	1.48
β1,3	Midsize Car	0,1	0.592	5.55
β1,4	Large Car	0,1	0.648	5.55
β1,5	Sports Car	0,1	0.464	3.67
β1,6	Subcompact Crossover	0,1	0.413	2.96
β1,7	Compact Crossover	0,1	0.702	5.20
β1,8	Midsize Crossover/SUV	0,1	1.188	8.95
β1,9	Large SUV	0,1	1.241	8.91
β1,10	Small Van	0,1	0.824	5.45
β1,11	Full-size/large Van	0,1	1.214	8.09
β1,12	Small Pickup Truck	0,1	0.953	6.54
β1,13	Full-size/large Pickup Truck	0,1	1.640	11.18
β1,14	Industry Group 2 X Car	0,1	0.000	NA
β1,15	Industry Group 2 X SUV	0,1	-0.043	-0.27
β1,16	Industry Group 2 X Van	0,1	-0.299	-1.57
β1,17	Industry Group 2 X Pickup	0,1	-0.340	-1.80
β1,18	Industry Group 3 X Car	0,1	0.000	NA

	Variable	Units	Coef.	T-Stat
β1,19	Industry Group 3 X SUV	0,1	-0.213	-1.98
β1,20	Industry Group 3 X Van	0,1	-0.237	-1.72
β1,21	Industry Group 3 X Pickup	0,1	-0.414	-3.38
β2,1	Gasoline only	0,1	0.000	NA
β2,2	Gas HEV	0,1	-0.195	-4.18
β2,3	PHEV	0,1	-1.557	-7.97
β2,4	Diesel	0,1	-0.319	-3.01
β2,5	BEV	0,1	-0.847	-3.43
β2,6	FCV	0,1	-1.002	-4.67
β2,7	PFCV	0,1	-1.702	-6.00
β2,8	Industry Group 1 X ZEV	0,1	0.000	NA
β2,9	Industry Group 2 X ZEV	0,1	0.469	3.76
β2,10	Industry Group 3 X ZEV	0,1	0.474	6.54
β3,1	Standard	0,1	0.000	NA
β3,2	Premium	0,1	0.372	6.09
β4,1	New	0,1	0.000	NA
β4,2	Used (3 Years Old)	0,1	-0.409	-8.87
β4,3	Used (6 Years Old)	0,1	-0.677	-9.45
β5	Vehicle price	ln($1000)	-0.555	-9.48
β6	Total Range	ln(Miles)	0.170	3.54
β7	Share of stations with diesel	%	0.198	1.06
β8	Distance to hydrogen station	Miles	-0.007	-2.20
β9,1	Distance to Level 2 charger	Minutes	-0.003	-0.72
β9,2	Distance to Fast charger	Minutes	0.004	1.06
β9,3	Wait time for Fast charger	Minutes	-0.004	-1.74
β10,1	No home charging	0,1	0.000	NA
β10,2	Home charging	0,1	0.708	5.21
β11,1	No work charging	0,1	0.000	NA
β11,2	Work charging: Level 2	0,1	0.047	0.82
β11,3	Work charging: Fast	0,1	0.147	2.46
β12	MPG or MPGe	Miles per gallon	0.006	4.86
β13	Fuel cost per 100 miles	ln($1000)	-0.169	-4.32
β14,1	Level 2 charge time to go 10 miles	Minutes	0.002	0.82
β14,2	Level 2 charge time 10% to 80% charge	Hours	-0.005	-0.63
β14,3	Fast charge time 10% to 80% charge	Minutes	-0.003	-1.84
β15,1	No purchase incentive	0,1	0.000	NA
β15,2	HOV lane incentive	0,1	0.071	1.02
β15,3	Tax incentive	$1000	0.034	3.93
β15,4	Rebate incentive	$1000	0.026	2.29
β16	Annual maintenance cost	ln($1000)	-0.324	-5.51
β17	0-60 MPH acceleration	Seconds	-0.017	-1.87
β18,1	Vehicle Class = Car X Share of cars in fleet	%	0.540	5.04
β18,2	Vehicle Class = SUV X Share of SUVs in fleet	%	0.695	6.60
β18,3	Vehicle Class = Van X Share of vans in fleet	%	1.344	11.29

	Variable	Units	Coef.	T-Stat
β18,4	Vehicle Class = Pickup X Share of pickups in fleet	%	1.378	12.63

Source: 2024 California Vehicle Survey, California Energy Commission

Table 152: Commercial Vehicle Choice Model by Industry Type, Fit Statistics

Fit Statistics	Value
Number of Observations	2120
Number of Individuals	16960
Null Log-Likelihood	-23511.55
Final Log-Likelihood	-14927.88
Adjusted Rho-Square	0.3627

Source: 2024 California Vehicle Survey, California Energy Commission

In this model, respondents in Industry Group 3 were associated with lower levels of utility for pick-up trucks. Respondents in Industry Groups 2 and 3 were associated with higher levels of utility for ZEVs. In addition, β_{18} suggested that all respondents' utility increased with vehicles in the same broad class as most of the vehicles in their current fleet.

Commercial Autonomous Vehicle Choice Models

As with the residential survey, commercial respondents were shown four supplemental SP experiments in which they chose a level of autonomy for one of the vehicles they selected in a vehicle choice experiment. The data from these AV choice experiments were then merged with the data for estimating the vehicle choice experiments described in the previous section to estimate a joint model based on both data sources. Based on the estimation results, RSG does not recommend that the autonomy level choice model based on the autonomous vehicle DCE be used to forecast autonomous vehicle demand for the same reasons laid out in the residential autonomous vehicle choice model section.

Appendix J of this report includes the specification of a model based only on data from the AV DCE, a model that is jointly estimated on both data from the AV DCE and data from the vehicle type DCE. Both of these specifications indicate general inconsistency among respondents' preferences for AVs. However, in an additional specification of the joint model, the project team finds that when the reference vehicle in the AV DCE was a BEV, the estimated effect of increasing levels of autonomy on respondents' utility was positive and statistically significant. This finding suggests that among the subset of commercial respondents who say they would purchase a BEV, they might also be interested in AV technologies for BEVs.

Appendix J also includes a specification of the autonomous vehicle choice model with interactions by industry type. No industry type is associated with a positive effect on commercial utility for any level of autonomy.

Summary and Conclusion

Estimations were successfully conducted for six models in the residential market segment and two commercial vehicle type choice models. The coefficient estimates were generally found to be statistically significant and intuitively correct in terms of sign and magnitude and are comparable with the coefficients estimated during previous iterations of the CVS. The project team conducted specifications tests in each analysis to find the number and form of variables with the most explanatory power.

Key results from the modeling tasks include the following:

- BEV fuel type vehicles are associated with roughly the same utility as gasoline vehicles for households in all vehicle ownership categories.
- The vehicle attributes with the largest impact on household utility are vehicle price and the presence of home charging systems for BEVs and PHEVs.
- Current ZEV owners are associated with higher household utility levels for ZEVs than non-ZEV owners.
- Increased household utility for increasing autonomy levels were found only among ZEVs.
- The strongest predictor of vehicle replacement is geography; households in urban areas are much more likely to replace a vehicle in the next year than those not in urban areas.
- The strongest predictor of vehicle quantity is household income; households with higher incomes are associated with increasingly positive utility for owning two and three or more vehicles.
- The strongest predictor of increasing VMT is the number of workers in a household.
- Commercial operators strongly prefer gasoline fueled vehicles to other fuel types, but operators who have ZEVs in their fleets are associated with increasing utility for ZEVs.
- Increased commercial utility for increasing autonomy levels were found only among ZEVs.

The application of these coefficient estimates in the PVC and CVC models will allow the Energy Commission to forecast vehicle fleet composition, VMT, and fuel consumption in California and to analyze strategies for reducing petroleum dependency in the state.

CHAPTER 9: Recommendations

The 2024 California Vehicle Survey provides valuable data about the transportation and energy usage patterns of Californians. Chapters 7 and 8 of this report underscored the value of these data by demonstrating insights into:

- current vehicles owned,
- transportation habits,
- knowledge of and experience with alternative fuel types,
- charging patterns of respondents who own a plug-in vehicle,
- experience with and attitudes about autonomous vehicle technologies, and
- interest in vehicle-to-grid integration technologies.

In designing, implementing, and analyzing the data for the 2024 CVS, RSG developed a series of recommendations for future iterations of the survey that are summarized below.

Survey Questionnaire

As with past iterations of the CVS, the 2024 CVS questionnaires required a significant level of effort to complete, particularly for large households or households and businesses with many vehicles. The average time required to complete the entire questionnaire was more than 30 minutes for residential respondents and more than 25 minutes for commercial respondents. This level of respondent burden adversely affected survey completion rates. Reducing the number of questions where possible, especially in the question loops specific to each household member and each household or commercial fleet vehicle, would likely improve completion rates for both surveys.

Furthermore, survey response rates were considerably lower than past iterations of the CVS, so RSG recommends increasing the amount of the participation incentive or anticipating no higher than a 2.5 percent response rate among residential respondents.

ZEV Owner Sampling Frame

Given the proliferation of ZEV ownership among Californians, the 2024 CVS suggests that future iterations of the project should not include a distinct sampling frame for residential and commercial ZEV owners.

In the general residential address-based sample and the panel respondents, 20 percent of respondents owned a ZEV and completed the ZEV survey. These respondents accounted for 57 percent of ZEV survey responses. Moreover, 9 percent of respondents from the ZEV sampling frame did not report owning a ZEV at the time of the survey and did not complete the ZEV survey.

Similarly, in the commercial survey, 12 percent of respondents recruited from the general ABS method reported owning a ZEV, and these respondents accounted for 72 percent of all completed ZEV commercial surveys. Of respondents recruited with the commercial ZEV sampling frame, 45 percent did not report owning a ZEV at the time of the survey and did not complete the ZEV survey.

Consideration Set

As in the 2019 CVS, the vehicle type discrete choice experiments were designed to include vehicles with attributes that aligned with the purchase intentions of the respondent. As discussed in Chapter 3, this inclusion was done to make the alternative in the experiments more relatable to the respondent. However, this process creates more questions for the respondent to answer and makes the alternatives in each DCE endogenous to the respondents' preferences.

One possible solution to this issue would be to make the combinations of vehicle type, fuel type, prestige, and vehicle age shown in the experiments based on the distribution of these attributes in the current California LDV fleet. While this solution may mean that some respondents may be shown a vehicle they would be unlikely to buy, this change would reduce the burden on respondents and decrease the bias in the estimates due to endogeneity that is introduced with the consideration set.

Stated Preference Questions

The stated preference experiments in the 2024 CVS were complex with 14 attributes presented across four vehicle alternatives. Coefficients estimated for certain attributes in the vehicle choice model have exhibited a low level of statistical significance in several iterations of the CVS, namely fuel station availability, distance to public charging, work charging availability, HOV incentives, and acceleration. The low statistical significance implies that, on average, these vehicles and refueling attributes do not have a significant impact on vehicle choice. These attributes should be evaluated and revised or removed in future surveys to reduce the amount of information presented in each experiment.

Autonomous Vehicle Discrete Choice Experiments

The 2024 CVS included a novel DCE for AV autonomy level choice. While these experiments did yield interesting results, the model results suggested that participants had inconsistent preferences about AV technology and were resistant to purchasing AVs. Future iterations of the CVS could include AV autonomy level choice questions in the following ways:

- As an attribute of BEV vehicles in the vehicle type DCE. Perhaps by the time the next CVS is administered respondents will be more familiar with the concept of personally owned AVs. However, because these vehicles are not available alternatives in the vehicle market, respondents may have struggled to value the respective levels of autonomy.
- As an attribute of a choice for vehicle quantity or transaction and replacement models. Because AVs are most familiar to participants as ride hailing services rather than personal vehicles, access to AV ride hailing services might influence people's likelihood of replacing vehicles or owning more vehicles.
- As an attribute in a novel mode choice model. Because AV ride hailing is likely to become more widespread in coming years, demand for AV ride hailing services — and the vehicle charging infrastructure that supports them — might be fruitfully modeled in a mode choice — rather than a vehicle choice — model.

GLOSSARY

AUTONOMOUS VEHICLE (AV) — A vehicle that is equipped with systems that can perform the task of driving with varying levels of involvement by a human driver. The Society of Automotive Engineers (SAE) categorizes autonomous vehicles into the following five autonomy levels:

- Level 1 (Driver Assistance): The vehicle can assist with either steering or acceleration/deceleration, but the human driver must remain fully engaged.
- Level 2 (Partial Automation): The vehicle can control both steering and acceleration/deceleration, but the human driver must continuously supervise and remain the primary driver.
- Level 3 (Conditional Automation): The vehicle can perform all driving tasks under certain conditions, but the human driver must be available to take control when requested.
- Level 4 (High Automation): The vehicle can operate without human input in specific conditions or environments (e.g., geofenced areas), even if a human does not respond or without a human driver at all.
- Level 5 (Full Automation): The vehicle is fully autonomous in all driving environments and conditions, with no need for a human driver at any time.

The AV DCEs in this survey, combined autonomy Levels one and two into "base level" for comparison with higher levels of autonomy. Base level autonomy features are already present in light duty vehicle models in the market.

CALIFORNIA ENERGY COMMISSION (CEC) — The state agency established by the Warren-Alquist State Energy Resources Conservation and Development Act in 1974 (Public Resources Code, Sections 25000 et seq.) responsible for energy policy and planning.

DIESEL OIL — Fuel for diesel engines obtained from the distillation of petroleum. It is composed chiefly of aliphatic hydrocarbons. The fuel volatility is similar to that of gas oil.

FUEL CELL ELECTRIC VEHICLE (FCEV) — A vehicle powered by hydrogen and converts it to electricity through a fuel cell, producing only water vapor and warm air as emissions. They are more efficient than internal combustion engine vehicles while offering similar ranges and refuel times.

HYBRID ELECTRIC VEHICLE (HEV) — A vehicle that combines an internal combustion engine with a battery and electric motor. This combination offers the range and refueling capabilities of a conventional vehicle, while providing improved fuel economy and lower emissions.

LIGHT-DUTY VEHICLE (LDV) — Any motor vehicle with a gross vehicle weight of 10,000 pounds or less.

PLUG-IN FUEL CELL ELECTRIC VEHICLE (PFCEV) — PFCEVs combine elements of both plug-in electric vehicles and fuel cell electric vehicles. They are powered by hydrogen, which is converted to electricity by a fuel cell, and they have a battery that can be charged via an external power source. PFCEVs produce no harmful tailpipe emissions, only emitting water vapor and warm air.

PLUG-IN HYBRID ELECTRIC VEHICLE (PHEV) — PHEVs are powered by an internal combustion engine and an electric motor that uses energy stored in a battery. The vehicle can be plugged in to an electric power source to charge the battery. Some can travel nearly 100 miles on electricity alone, and all can operate solely on gasoline (similar to a conventional hybrid).

VEHICLE-TO-GRID (V2G) — A technology that allows electric vehicles to communicate with and supply power back to the electrical grid. This enables energy storage and management, helping to balance grid demand, support renewable energy integration, and provide backup power during outages.

ZERO-EMISSION VEHICLE (ZEV) — Vehicles which produce no emissions from the on-board source of power (e.g., an electric vehicle).